NDCEE

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Acronyms & Abbreviations

AAP	Army Ammunition Plant
ACOR	Alternate Contracting Officer's Representative
AEC	Army Environmental Center
AFB	Air Force Base
AFRL	Air Force Research Laboratory
ALC	Air Logistics Center
ANAD	Anniston Army Depot
B&L	Bouldin & Lawson
BOD	Biochemical oxygen demand
BRAC	Base Realignment and Closure
BTTN	1,2,4-butanetriol trinitrate
BuNENA	N-butyl-2-nitratoethylnitramine
CCAD	Corpus Christi Army Depot
CEG-A	Combat Equipment Group-Afloat
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERL	Construction Engineering Research Laboratory
CFR	Code of Federal Regulations
CO_2	Carbon dioxide
COD	Chemical oxygen demand
COR	Contracting Officer's Representative
COTS	Commercial off-the-shelf
CrN	Chromium nitride
CRT	Cathode ray tube
CTC	Concurrent Technologies Corporation
DC	Direct current
DCC-W	Defense Contracting Command - Washington
DEER2	Demanufacturing of Electronic Equipment for Reuse and Recycling
DEGDN	Diethyleneglycol dinitrate
DLA	Defense Logistics Agency
DLC	Diamond-like carbon
DoD	Department of Defense
DRE	Destruction and removal efficiency
DRMO	Defense Reutilization and Marketing Office
DRMS	Defense Reutilization and Marketing Service
DSCR	Defense Supply Center Richmond
ECAM℠	Environmental Cost Analysis Methodology

ECCP	Electrically conducting composite pipes
EHC	Electroplated hard chromium
EHS	Environmental, health, and safety
EIS	Electrochemistry impedance spectroscopy
EL/MS	Ethyl lactate/methyl soyate
EN	Electroless nickel
ENP	Electroless nickel-phosphorus
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ESD	ElectroSpark Deposition
ESP	Electrostatic precipitators
FBG	Fiber Bragg Grating
FC*Tec*	Fuel Cell Test and Evaluation Center
FEMMS	Facility Environmental Management and Monitoring System
FUDS	Formerly Used Defense Sites
FY	Fiscal year
GAC	Granular activated carbon
H_2	Hydrogen
H_2O_2	Hydrogen peroxide
HAP	Hazardous air pollutant
HEMTT	Heavy Expanded Mobility Tactical Truck
HEPA	High-efficiency particulate air
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HMX	Cyclotetramethylene-tetranitramine
HVLP	High-volume low-pressure
HVOF	High-velocity oxy-fuel
IAAAP	Iowa Army Ammunition Plant
IBAD	Ion beam assisted deposition
ICP	Instrumented cathodic protection
IEC	Industrial Ecology Center
LBP	Lead-based paint
LPR	Linear polarization resistance
IRR	Internal rate of return
ITRC	Interstate Technology Regulatory Council
IVD	Ion vapor deposition
JG-PP	Joint Group on Pollution Prevention
J-LONS	Joint Laser Ordnance Neutralization System

JUXOCO	Joint UXO Coordination Office
kW	Kilowatt
LAN	Local area network
LASER	Light Amplification by Stimulated Emission of Radiation
LCAAP	Lake City Army Ammunition Plant
LEAI	Light Energy Absorbing Igniter
LISI	Laser-Induced Surface Improvements
LPR	Linear polarization resist
LSAAP	Lone Star Army Ammunition Plant
MACOM	Major Command
MAIM	Magnetically Assisted Impaction Mixing
MANATEE	Managing Army Technologies for Environmental Enhancements
MEMS	Micro-electromechanical system
MIC	Metastable interstitial composites
MLAAP	Milan Army Ammunition Plant
MFH	Military Family Housing
Mo	Molybdenum
MRF	Materials Recovery Facility
MS	Methyl soyate
MSW	Municipal solid waste
NA	Not applicable
NAB	Naval Amphibious Base
NADEP-JAX	Naval Air Depot, Jacksonville
NAVAIR	Naval Air Systems Command
NAVEODTECHDIV	Naval Explosive Ordnance Disposal Technology Division
NAVSEA	Naval Sea Systems Command
NC	Nitrocellulose
NDCEE	National Defense Center for Environmental Excellence
Nd:YAG	Neodymium doped yttrium aluminum garnet
NG	Nitroglycerine
Ni	Nickel
NLOS	Non-line-of-sight
NNSY	Norfolk Naval Shipyard
NOx	Nitrogen oxide
NPDES	National Pollutant Discharge Elimination System
NPV	Net present value
NSWC-CD	Naval Surface Warfare Center, Carderock Division

OASA(I&E) [ESOH]	Office of Assistant Secretary of the Army (Installations and Environment) [Environment, Safety, and Occupational Health]
OC-ALC	Oklahoma City Air Logistic Center
ODS	Ozone-depleting substance
OSHA	Occupational Safety and Health Act (or Administration)
PACVD	Plasma-assisted chemical vapor deposition
PCCP	Prestressed concrete cylindrical pipe
PCMS	Passive countermeasure system
PDA	Personal digital assistant
PEO	Polyethylene oxide
PGDN	Propylene glycol dinitrate
PHNSY	Pearl Harbor Naval Shipyard
PMMS	Portable Munitions Monitoring System
PNNL	Pacific Northwest National Laboratory
ppb	Parts per billion
ppm	Parts per million
psi	Pounds per square inch
psig	Pounds per square inch @ gauge
PSII	Plasma source ion implantation
PVD	Physical vapor deposition
Radome	Radar domes
RCRA	Resource Conservation and Recovery Act
RDX	Cyclotrimethylene-trinitramine
REDMAP	Radford Environmental Development and Management Program
RF	Radio frequency
RFAAP	Radford Army Ammunition Plant
RIA	Rock Island Arsenal
SAC	Strong acid cationic
SAFR	Small arms firing range
SARA	Superfund Amendments and Reauthorization Act
SBA	Strong base anionic
$SCCO_2$	Supercritical carbon dioxide
SCR	Selective catalytic reduction
SERDP	Strategic Environmental Research and Development Program
SHT	Special hull treatment
SIMA	Shore Intermediate Maintenance Activity

TACOM	Tank-automotive and Armaments Command
TACOM-ARDEC	TACOM - Armament Research, Development & Engineering Center
TARDEC	Tank Automotive Research, Development and Engineering Center
TBP	Thermophilic (Biological) Process
TCP	Trivalent chromium pretreatment
TEGDN	Triethyleneglycol trinitrate
TMETN	1,1,1-trimethylolethane trinitrate
TNT	2,4,6 trinitrotoluene
TRAP	Telepresent Rapid Aiming Platform
TYAD	Tobyhanna Army Depot
UHPWJ	Ultrahigh-pressure waterjet
U.S.	United States
USDA	U.S. Department of Agriculture
UTC	United Technologies Corporation
UV	Ultraviolet
UXO	Unexploded ordnance
VOC	Volatile organic compound
W	Tungsten
WAC	Weak acid cationic
WBA	Weak base anionic
WPAFB	Wright-Patterson Air Force Base

OVERVIEW

NDCEE

the missing piece to today's environmental solutions

Introduction

In 1990, the U.S. Congress established the National Defense Center for Environmental Excellence (NDCEE) as the national resource for developing and disseminating advanced environmental technologies. Since that time, the NDCEE has provided technology evaluation, verification, implementation, and other services to hundreds of Department of Defense (DoD) installations, DoD prime contractors, other government agencies, and industry.

The NDCEE is focused on end-user needs and achieving specific performance-based results. It helps speed up technology development and deployment while integrating environmental decisions into the life cycle of a weapon system. It also ensures that technologies are implemented efficiently and effectively, using benchmarking and appropriate metrics.

The NDCEE emphasizes risk reduction, cost savings, enhanced readiness, and environmental excellence by:

- Focusing on pollution prevention activities that have positive financial impacts
- Transferring technologies through an approach that demonstrates and validates technologies
- Leveraging other tasks to eliminate duplication of efforts.

Technology transfer is the ultimate measure of success and is the positive outcome of technology evaluation and verification. To date, over 225 transfers and/or demonstrations of tangible technologies have been completed or scheduled. These technologies include manufacturing materials and processes, environmental treatment and control devices, and site assessment and clean-up technologies. In addition, nearly 400 tools, products, and services have been developed by the NDCEE. Examples of such items include training, environment cost analyses, databases, geographical information systems, risk analyses, and information exchanges.

This second *NDCEE Annual Technologies Publication* was prepared and submitted in fulfillment of the requirement under Task N.321, "NDCEE Mission Support." This document contains the results of the NDCEE's technology demonstration and transfer activities in fiscal year (FY) 2003.

During FY03, the NDCEE addressed 34 technologies. A summary on each technology has been created that describes the technology; its benefits and advantages; its limitations; specific FY03 NDCEE accomplishments; NDCEE economic analysis findings (if applicable), including capital and operating cost estimates as well as payback periods; suggested implementation applications; points of contact; and applicable NDCEE tasks.

To aid readers in identifying technologies that may solve their specific challenges, each summary features a box that states a generic DoD need that the technology addresses. Also identified are the Services' specific high-priority needs. The need codes were obtained from each Service's requirements report, as cited in the reference section of this document.

In conjunction with the above technology activities, the NDCEE operates a Demonstration Facility, described on page 89. Immediately following the facility description are summary sheets on each of the technologies located in the NDCEE Demonstration Facility.

Collaborative Relationships

Collaborative relationships are an integral component to the NDCEE's success at identifying, demonstrating, validating, and implementing solutions for clients. From the onset of a task, the NDCEE works intimately with the client to understand their unique concerns, challenges, and needs. Wherever appropriate, the NDCEE also collaborates with other stakeholders in the quest for a cost-effective, technically viable solution that is most appropriate for a client's unique circumstances.

The NDCEE works with a wide variety of organizations within the DoD. The NDCEE also works with other federal agencies, academic institutions, and private industry. More than 50 of these entities, listed below, were involved with the technology activities featured within this document.

Aberdeen Test Center, Aberdeen Proving Ground, Maryland

Air Force Research Laboratory (AFRL), Wright-Patterson Air Force Base, Ohio

Anniston Army Depot (ANAD), Alabama

Corpus Christi Army Depot (CCAD), Corpus Christi, Texas

Defense Contracting Command - Washington (DCC-W), Washington, DC

Defense Logistics Agency (DLA)

Defense Reutilization and Marketing Service (DRMS)

Defense Supply Center Richmond (DSCR)

Fort Benning, Georgia

Fort Bragg, North Carolina

Fort Dix, New Jersey

Fort Eustis, Virginia

Fort Hood, Texas

Fort Ord, California

Fort Shafter, Hawaii

Fort Story, Virginia

Hill Air Force Base (AFB), Utah

Indian Head Naval Surface Warfare Center, Maryland

Industrial Ecology Center (IEC), Picatinny Arsenal, New Jersey

Interstate Technology Regulatory Council (ITRC)

Iowa Army Ammunition Plant (IAAAP), Middletown, Iowa

Joint Group on Pollution Prevention (JG-PP)

Joint UXO Coordination Office (JUXOCO)

Lake City Army Ammunition Plant (LCAAP), Independence, Missouri

Lone Star Army Ammunition Plant (LSAAP), Texarkana, Texas

Marine Corps Logistics Base, Yermo Annex, Barstow, California

Milan Army Ammunition Plant (MLAAP), Tennessee

Natick Soldier Center, Natick, Massachusetts

Naval Air Systems Command (NAVAIR)

Naval Amphibious Base (NAB) Little Creek, Virginia

Naval Aviation Depot - Cherry Point, North Carolina

Naval Aviation Depot - Jacksonville (NADEP-JAX), Florida

Naval Aviation Depot - North Island, California

Naval Sea Systems Command (NAVSEA)

Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV), Indian Head, Maryland

Naval Surface Warfare Center, Carderock Division (NSWC-CD), West Bethesda, Maryland

New Mexico State University - Physical Science Laboratory, Las Cruces, New Mexico

Office of the Assistant Secretary of the Army for Installations and Environment [Environment, Safety and Occupational Health] (OASA(I&E)[ESOH])

Office of Naval Research

Ogden Air Logistics Center (ALC), Utah

Oklahoma City Air Logistics Center (OC-ALC), Tinker AFB, Oklahoma

Pacific Northwest National Laboratory

Patuxent River Naval Air Warfare Center, Aircraft Division, Maryland

Pearl Harbor Naval Shipyard (PHNSY), Hawaii

Radford Army Ammunition Plant (RFAAP), Virginia

Rock Island Arsenal (RIA), Illinois

Schofield Barracks, Hawaii

Shore Intermediate Maintenance Activity (SIMA), Mayport, Florida

Tobyhanna Army Depot (TYAD), Pennsylvania

Trident Refit Facility (TRF), Kings Bay, Georgia

U.S. Army Combat Equipment Group-Afloat (CEG-A), Goose Creek, South Carolina

U.S. Army Corps of Engineers

U.S. Army Engineer Research and Development Center/Construction Engineering Research Laboratory (ERDC/CERL), Champaign, Illinois

U.S. Army Environmental Center (AEC), Aberdeen Proving Ground, Maryland

U.S. Army Kwajalein/Regan Test Site, Marshall Islands

U.S. Army Tank-automotive and Armaments Command - Armament Research, Development & Engineering Center (TACOM-ARDEC)

U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), Warren, Michigan

U.S. Department of Agriculture (USDA)

U.S. Environmental Protection Agency (EPA)

U.S. TARDEC Fuels and Lubricants Research Facility, San Antonio, Texas

White Sands Missile Range, New Mexico

Wright-Patterson Air Force Base (WPAFB), Ohio

NDCEE Technical Approach

The NDCEE technical approach recognizes and focuses on opportunities for both vertical and horizontal technology promotion and transfer within the DoD. The objective of the NDCEE's approach is to transfer technically sound technologies that are economically feasible, environmentally friendly, and meet all stated objectives such that the DoD's overall return on investment and avoidance of effort duplication are maximized. We designed our approach to help facilities reduce the technical, cost, schedule, and/or regulatory risks that are commonly associated with implementing new technologies. The NDCEE's approach complements the technology transfer activities that are managed by the Joint Services such as those under the Army's Environmental Quality Technology Program.

As explained more thoroughly on the following pages, the approach has five key phases, of which any or all may be performed depending on the task scope:

1. Problem Definition
2. Alternatives Identification and Assessment
3. Technology Testing and Demonstration
4. Technology Justification and Validation
5. Technology Transfer.

In validating the approach, the NDCEE has sharpened the process of optimizing and implementing a technology. Key process elements include determining the nature and seriousness of client problems, identifying and assessing potential technology solutions, conducting laboratory and/or field testing on technologies according to client-approved test plans, and identifying and engaging stakeholders to optimize and implement technology solutions at their installations. The NDCEE produces comprehensive technology transfer data packages to proliferate the adoption of a solution across the DoD and other Government agencies.

All of the technologies featured in this publication are beneficiaries of the NDCEE technical approach.

1. Problem Definition

The approach to initiating any task is rooted in the belief that the keys to successfully developing a viable solution are proper scope definition, intelligent project planning, and stakeholder coordination. It also requires a comprehensive investigation and understanding of the nature and seriousness of the problem.

To assure a client-centric approach to addressing DoD environmental challenges, the NDCEE works closely with clients to fully understand their requirements and interests. Typically, these requirements are determined by establishing a baseline of the current process and materials and considering the problems and advantages of the current process as well as future environmental requirements.

2. Alternatives Identification and Assessment

Using criteria that are developed during a baseline analysis, the NDCEE identifies and evaluates technologies that have the potential to meet client requirements. This process begins with an exhaustive literature review and database search to gain a thorough understanding of available-as well as emerging-technical solutions. Our network of industry and academic contacts is also tapped to identify current best practices and state-of-the-art technology application and development efforts. Additionally, we leverage knowledge and experience obtained through the execution of similar tasks to extract and apply lessons learned. This initial review, outreach, and leveraging is a cost-effective investment that

ultimately prevents duplication of effort. Further, it provides the NDCEE with a compilation of pertinent technical references, business information, patent and trademark literature, and ongoing research studies, from which a successful solution may be discovered.

As part of the assessment process, the NDCEE systematically identifies data gaps and evaluates known risks and benefits associated with technology alternatives. We screen identified alternatives against quantifiable criteria established with project stakeholders and approved by the Government to arrive at an optimal list of candidates for testing. Because alternatives are reviewed and analyzed in a consistent manner from multiple viewpoints [technical, financial, operational, and environmental, health and safety (EHS)] using a systematic engineering approach, future technology transfer risks are minimized. From here, the NDCEE makes specific recommendations to the client organization to help it meet its technology needs.

3. Technology Testing and Demonstration

Using client-approved test plans and health and safety plans, the NDCEE conducts laboratory tests and/or field demonstrations on technology candidates to collect information on the technologies' abilities to meet the specified user requirements. Specifically, data on performance, cost, predictability, and EHS risks are collected. When necessary, the NDCEE designs laboratory and bench-scale test equipment to meet testing requirements and/or laboratory test procedures.

The demonstration process encompasses feasibility, optimization, and validation testing. As necessary, it also includes obtaining regulatory permits, developing equipment designs, identifying operational and maintenance requirements, and other related efforts. Feasibility testing is low-cost, bench-scale testing that is used to determine a technology's potential for meeting requirements. It is typically performed to eliminate those technologies with a low probability of meeting requirements before incurring high testing costs. Optimization testing is used to quantitatively define the operating conditions to meet performance requirements. Full-scale validation testing is typically performed either at a client's site under actual field conditions or in the NDCEE Demonstration Facility under simulated service conditions. Validation testing is used to determine if the process is robust (i.e., will meet performance requirements under typical service conditions) and to collect data to support cost, performance, and risk analyses.

Because technologies often benefit multiple users, the NDCEE encourages Government and industry stakeholders to attend demonstrations. This type of planned technology outreach allows interested and varied organizations to obtain a first-hand view of demonstration results as well as encourages technology adoption.

4. Technology Justification and Validation

As part of our recommendation process, the NDCEE conducts a technical, economic, and regulatory assessment of the candidate technologies to determine the most appropriate technology for meeting high-priority client requirements. The assessment is based on data systematically collected during the demonstration phase. To be a viable replacement for the DoD, the candidate technology has to meet or exceed existing performance and operational requirements, promote environmental stewardship, be cost-effective, and meet both current and future regulations.

Once the NDCEE determines that the technical requirements have been achieved, an economic analysis is undertaken in which the cost of a proposed investment is compared against its expected benefits. Using the Environmental Cost Analysis Methodology

(ECAM[SM]), demonstration results, and other relevant information, NDCEE specialists compare the financial aspects of each identified alternative against the baseline process and other candidates. The NDCEE uses standard financial indicators such as net present value (NPV), internal rate of return (IRR), and discounted payback period to compare and evaluate technologies.

Compliance with Executive Orders and state and federal environmental statutes and regulations are another consideration in the justification process. In many instances, the driver for technology implementation is improved environmental regulatory compliance. Failure to comply with environmental regulations [e.g., exceeding regulatory limits on ozone-depleting substances (ODSs), volatile organic compounds (VOCs), and/or hazardous air pollutants (HAPs)] could result in excessive costs, fines, and public outcry. Adverse publicity and impacts on worker health and safety cannot be easily quantified, but they could be the most damaging result for the DoD. Examples of potentially applicable environmental and work safety statutes and related regulations include the Occupational Safety and Health Act (OSHA); Clean Air Act; Clean Water Act; Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Resource Conservation and Recovery Act (RCRA); and Superfund Amendments and Reauthorization Act (SARA).

5. Technology Transfer

Successful technology transfer is largely dependent on successful information dissemination. The NDCEE's work products are targeted at providing DoD decision makers with the information that is necessary to make informed decisions and embrace technologies that are validated by the NDCEE. Technology transfer data packages typically consist of a design package, performance assessment, cost assessment, operation and maintenance manual, and training packet and tools that are developed while validating an alternative material, process, or technology. Often these data packages are supplemented with a pictorial record or video. Providing easy-to-understand, compelling information packages promotes the widespread adoption of technologies for increased return on DoD investments.

The NDCEE supports the full-scale implementation of the selected technology at a client site by providing assistance in appropriate areas such as technology procurement, installation startup, process optimization and operator training. We also offer follow-on technical services to resolve "new user" challenges as they are identified. Lessons learned from these follow-up visits are incorporated into the technology transfer data package. Likewise, any operational problems that cannot be readily fixed are thoroughly investigated to develop recommendations for process or equipment modifications or procedural changes.

TECHNOLOGIES

NDCEE

the missing piece to today's environmental solutions

Automatic Corrosion Inhibitor Application System for Army Tactical Vehicles

The NDCEE is identifying, investigating, and developing environmentally friendly technologies that can be used to measure, control, and prevent corrosion. The NDCEE has designed, built, and implemented a prototype Automatic Corrosion Inhibitor Application System for Army Tactical Vehicles. This facility is being used to optimize the final facility design and processing variables, allowing formal specifications and operating procedures to be generated. The findings are being applied to construct and operate new corrosion inhibitor application facilities at U.S. Army shipping locations, maintenance facilities, and depots.

Technology Description

The Automatic Corrosion Inhibitor Application System for Army Tactical Vehicles automatically cleans vehicles and then applies a corrosion inhibitor for metal protection. It relieves operators from manually applying the inhibitor to tactical ground vehicles prior to shipboard transportation.

The portable system was designed based on user requirements and offers cost, environmental, health, and safety improvements over the manual application process. It utilizes commercial off-the-shelf (COTS) equipment to both wash the vehicles and apply a corrosion inhibitor in less than half of the time associated with the manual application process. In addition to operator benefits, the system reduces process wastes and contains a closed-loop reclamation system that reduces wastewater discharges.

The NDCEE designed and installed a prototype facility at Fort Hood. Vehicles are driven into the facility and undergo an automatic wash cycle in preparation for the corrosion inhibitor application. The vehicles then reenter the facility to receive the corrosion inhibitor, which is applied using the same spray equipment as the automated wash operation. All liquids are recycled using a closed-loop system.

The application system is very efficient with the corrosion inhibitor during application. Due to reduced drying times, a system-treated vehicle is processed within one day rather than the three days that were previously needed with a manual application. Corrosion inhibitor drag out also is reduced.

DoD Need

Corrosion prevention in tactical vehicles

Technology Benefits and Advantages

- Is a modular system that can be configured to treat a variety of vehicle sizes and meet the required throughput
- Utilizes COTS equipment to both wash the vehicles and apply a corrosion inhibitor in less than half of the time that is associated with the manual application process
- Prevents the formation of corrosion in vehicles
- Improves mission readiness through reduced risk of vehicle failure
- Reduces maintenance costs associated with corrosion protection of ground vehicles
- Reduces discharges to industrial wastewater treatment plants through a closed-loop system
- Has flexibility in design of inhibitor application facilities, which are nonintrusive to host site (system may be relocated as needed or incorporated into maintenance and logistics facilities)

The Automated Corrosion Inhibitor Application System for Army Tactical Vehicles automatically cleans vehicles, such as this HEMTT, and then applies a corrosion inhibitor for metal protection.

Technology Limitations

- System is still undergoing testing. Operating procedures still need to be evaluated for efficiency.
- Regulatory permits may be required.
- Facilities will require access to utilities, such as water and electricity.
- Additional space is needed for staging and curing areas, depending on expected throughput.

NDCEE FY03 Accomplishments

The NDCEE conducted field demonstration tests on the prototype facility at Fort Hood. Findings revealed that material and labor costs are approximately 40% lower and process times are approximately 30 minutes shorter per vehicle with the automated system than the traditional manual method.

Economic Analysis

The NDCEE conducted a cost-benefit analysis based on labor and materials that showed the system has a payback period of 12 months. Based on data from Fort Shafter, a manual operation has a payback of 16 months. An estimated total investment of approximately $270,000 is necessary to acquire equipment that is comparable to that which is installed at Fort Hood. The corrosion inhibitor is approximately $1,000 per 55-gallon drum, with an estimated 1 gallon of product used per vehicle. Other operational costs include utilities, labor, alkaline detergent, petroleum-decomposing enzymes, and personal protective equipment.

Suggested Implementation Applications

This technology can be installed at any maintenance facility or rapid deployment site that is used for trans-oceanic transports. The system was designed for use by all-wheeled tactical vehicles and ground support equipment such as Heavy Expanded Mobility Tactical Trucks (HEMTTs), High Mobility Multipurpose Wheeled Vehicles (HMMWVs), and M870 40-ton low-bed semi-trailers.

Points of Contact

- I. Carl Handsy, TACOM-ARDEC, (800) 325-2920 x47738, Handsyl@tacom.army.mil
- Albert Walker, COR Team, (410) 436-6867, Albert.Walker@aec.apgea.army.mil
- Wayne Powell, NDCEE, (727) 549-7216, powellw@ctcgsc.org

Applicable NDCEE Tasks

Corrosion Measurement and Control (Tasks N.255 and N.304)

Biobased Hydraulic Fluids

The NDCEE, in conjunction with TARDEC and the TARDEC Fuels and Lubricants Research Facility, identified, tested, and evaluated biobased hydraulic fluids for use in military equipment for DLA. The initial NDCEE evaluation, including working with industry leaders in biobased hydraulic fluid development, will facilitate establishing performance levels for biobased hydraulic fluids. The USDA plans to use project findings to assist in establishing biobased content ranges and definitions for future procurements of new biobased products. In FY04, under a new follow-on task, the NDCEE will be requesting reformulated samples from previous vendors for a third round of laboratory analysis based on military tactical equipment requirements. The NDCEE also will evaluate performance data of currently available off-the-shelf commercial grade biobased hydraulic fluids against existing government requirements for nontactical, construction-grade government equipment.

Technology Description

Biobased hydraulic fluids are derived from renewable plant resources and are generally more environmentally benign than their petroleum-based and synthetic counterparts. Hydraulic fluids, under pressure, transmit power to moving parts of many machines and equipment, including tanks, airplanes, cars, bulldozers, tractors, and most heavy equipment. Although presently formulated for commercial use, the new biobased fluids are being developed to meet more stringent military specifications.

All hydraulic fluids contain ingredients that reduce wear and enable the fluid to flow better, particularly in colder temperatures. They also have a high flash point for safety as well as antirust and antioxidation properties. Traditionally, petroleum-based fluids have been used because they are inexpensive and are currently in the DLA supply system. Biobased fluids are biodegradable, require fewer additives, and may perform better under heavier loads. They are becoming more readily available and less expensive.

For the NDCEE evaluation, TARDEC identified 10 target performance properties based on two demanding synthetic (MIL-PRF 46170) and petroleum-based (MIL-PRF 6083) hydraulic fluid military specifications for combat tactical vehicles. The specifications require cold temperature performance below -76°F (-50°C) and flash points above 392°F (200°C). In addition, candidate biobased lubricants were required to have a minimum biobased content of 25%, which all of the candidates met or exceeded. These fluids were proposed for further individual component and equipment testing.

DoD Need

Develop environmentally compatible lubricants and fluids

Service Need Numbers

Army: 3.7.l

Navy: 3.1.10.b

Technology Benefits and Advantages

- Is biodegradable, nontoxic, and nonflammable (depending on additives used)
- May provide greater operator safety than conventional hydraulic fluids
- Prevents cleanup liabilities and costs that are associated with spills and leaks of conventional hydraulic fluids
- Provides excellent lubricity, can be lower cost and have higher flash and fire points (which means they are safer to store and handle) than most synthetic lubricants
- May offer a better cost and performance profile than current products for many applications
- Helps the DoD to comply with Executive Orders 13101, 13123, 13134, 13148, and 13149 as well as RCRA and other regulations
- Is commercially available

The DoD intends to switch to biobased hydraulic fluids for combat tactical equipment, such as this Bradley Fighting Vehicle (foreground), M1A2 Abrams Main Battle Tank, and Landing Craft (in water), which currently use petroleum-based or synthetic hydraulic fluids.

Technology Limitations

- Fluids that can meet all of the military requirements for combat tactical vehicles are still in development.

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with identifying, testing, and evaluating biobased hydraulic fluids for use in military equipment for DLA. Activities included:

- Producing a Requirements Report that documented efforts to identify USDA and military "standards" regarding the testing and validation of biobased hydraulic fluids for intended applications. Sixteen candidates were submitted.
- Conducting a laboratory analysis (Part A) to determine whether products could meet the established military requirements. Although Part A candidate results were promising, none passed all of the DoD target performance requirements. Based on laboratory findings, 10 candidates were reformulated (Part B) and submitted for additional laboratory testing. In the Part B analysis, two of the reformulated fluids passed 8 and two others passed 7 out of 10 of the requirements, with all four narrowly missing passing all of the target requirements. The vendors indicated that reformulation based on the Part B results will likely lead to meeting all 10 target requirements. Laboratory results are contained in Parts A and B of the Alternatives Report.
- Producing a Demonstration Plan for future field-testing activities. Future field trials will use military equipment at an Army installation and a Navy and/or Air Force base under training scenarios.

Economic Analysis

Many types of petroleum-based hydraulic fluids contain constituents that are considered toxic or hazardous. As a result, leaking equipment can contaminate soils, groundwater, and surface water, polluting sensitive ecosystems where military maneuvers are conducted. Besides the incalculable costs to wildlife and their environment, restoration of fluid-contaminated sites can be costly to the Army, Air Force, and Navy.

The NDCEE conducted a life-cycle cost analysis that took into account purchasing, waste disposal, and spill costs. The current baseline costs for the purchasing and disposal of MIL-PRF 6083 and MIL-H 4617 hydraulic fluids are $9.28 and $13.88 per gallon, respectively. A spill event would add approximately $68 per gallon to those costs. These figures are derived from actual use and purchase data for Sandia National Laboratory. Biobased fluids have a purchase and disposal cost of $12 per gallon. In the event of a spill, no additional costs should be accrued because the material is biodegradable. Other costs may be associated depending on the size and location of the spill; however, these spill-related costs should be less than those associated with petroleum-based fluids.

Suggested Implementation Applications

The following general-purpose and tactical equipment currently use petroleum-based and synthetic fluids: Bradley Fighting Vehicle, M1A2 Abrams Main Battle Tank, Carrier Ammunition Carrier Command Post, Carrier Multiple Launch Rocket, Carrier Mortar 107mm, Carrier Personnel M113A2, Carrier Smoke Generator, Combat Vehicle ITV-M901A1, Infantry Fighting Vehicles, Landing Craft Mechanized LCM8, Landing Craft Utility, Lighter Air Cushion Vehicle 30-ton, Tank Combat Full Tracked, Armored Combat Earthmover ACE M9, Armored Recon ABN Assault Vehicle, Bridge Launcher Armored Vehicle, Carrier Ammunition, Crane Shovel 20-ton, Hammer Pile Drivers, and Howitzers.

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Applicable NDCEE Task

Pollution Prevention Initiative (Task N.227, Mod 1)

Biodegradation Processes for Propellant Constituents

Through the Managing Army Technologies for Environmental Enhancements (MANATEE) Program, the NDCEE is continuing to identify, evaluate, design, and deploy high-priority pollution prevention technologies that improve process efficiency and reduce wastes at Radford Army Ammunition Plant. In FY03, the NDCEE completed two pollution prevention projects at RFAAP. One project focused on identifying and quantifying ethanol losses from RFAAP's manufacturing processes. The second project evaluated, through bench-scale testing, biodegradation technologies for treating waste propellants.

Technology Description

Biodegradation technologies are being developed as potential treatment alternatives to open burning of waste propellants. Regulatory allowances for open burning are expected to be eliminated within 5–10 years.

Bench-scale tests were conducted on microbes from RFAAP's facultative biological process alone as well as mixed with microbes from NDCEE's Thermophilic (Biological) Process technology (see page 77 for its description). Three propellants were tested and are listed below along with their constituents.

1) M14 grit from grains: The grit particles are the size of coarse sand. M14 constituents include nitrocellulose, diphenylamine, 2-nitrodiphenylamine, dibutylphthalate, dinitrotoluene, and graphite.
2) PAP grit from grains: PAP constituents include nitrocellulose, ethyl centralite, Class-C Fly Ash 2, potassium sulfate (K_2SO_4), and graphite.
3) M36 paste (similar in composition to AA2 paste): The solid portions of paste are similar in dimension to grains of sand. M36 paste constituents include nitroglycerine, nitrocellulose, triacetin, 2-nitrodiphenylamine, lead copper resorcylate/salicylate, candelilla wax, and di-n-propyl adipate.

The tests were conducted at three different temperatures [room temperature of 77°F (25°C), 100°F (38°C), and 140°F (60°C)] to determine the effect of temperature on the degradation rate. The higher temperatures (100°F and 140°F) were achieved by immersing the bioreactors in a temperature-controlled water bath. The test condition was maintained for seven days, which included three days with aeration and four days without aeration. At the end of the seven-day period, the supernatant liquid was decanted. The test cycle was repeated twice. The parameters that were analyzed include pH, total settleable solids, chemical oxygen demand, nitroglycerine, dinitrotoluene, phthalates, diphenylamine, nitrate, ammonia, and sulfate. Of the three propellants tested, M36 paste propellant shows promise for partial biodegradation.

Technology Benefits and Advantages

- Shows promise for degrading propellant materials
- Reduces the settleable solids for propellants
- Poses limited health and safety risks; however, several propellant components are dangerous and precautions should be taken

Technology Limitations

- The processes are in the developmental stage.
- Operator training will be required.

DoD Need

An alternative to incineration and open burning for treating waste propellants

Service Need Numbers

Army: 3.3.a

Navy: 2.III.01.t

Propellant paste at RFAAP's Open Burning Ground

- Open-vessel processes should not be used to biodegrade propellants at 100°F and above because, at those elevated temperatures, the resultant foaming and evaporation are too difficult to control.

NDCEE FY03 Accomplishments

- Produced a System Decision Paper that discusses the findings of a literature study. In that report, the NDCEE recommended bench-scale testing RFAAP's facultative process to assess the potential capability of the technology to treat propellant constituents.
- Conducted bench-scale degradation tests on three propellants (M14 grits, PAP grits, and M36 paste). The bench-scale testing consisted of two biological processes that were conducted in duplicate plus controls. The test data were used to calculate the propellant constituent biodegradation rate and destruction and removal efficiency for these biodegradation processes. Testing was performed in accordance with the NDCEE-prepared, Government-approved Test Plan.
- Produced a Test Report that contains bench-scale test results and data analyses/ assessments. As a result of determining that the M36 paste propellant shows promise for partial biodegradation, the NDCEE recommended that biodegradation testing be continued. The objective would be to evaluate the toxicity of incrementally increasing propellant concentrations (e.g., M36 paste) to the microbes that are flourishing within RFAAP's wastewater treatment operations. Such testing will assist in determining the maximum propellant-loading rate into the biodegradation process.

Economic Analysis

Because the processes are in the developmental stage, no cost-benefit analyses have been conducted. However, costs are anticipated to be competitive because the processes would utilize RFAAP's indigenous microbes and existing biological treatment facilities for treating waste propellants.

Suggested Implementation Applications

The technologies are being developed for installations that use open burning as a means for treating waste propellants.

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Applicable NDCEE Task

Managing Army Technologies for Environmental Enhancements (Task N.310)

Electronic Equipment Demanufacturing Recycling and Reuse System

The NDCEE is demonstrating and validating improved technologies for the demanufacturing of electronic equipment. As part of its contributions, the NDCEE is revitalizing standards, procedures, and facility and equipment design associated with fostering a total life-cycle approach to managing electronic equipment. In the fall of 2003, the NDCEE transitioned these technologies to Lone Star Army Ammunition Plant. As a result of its expanded capability, LSAAP will be able to support the Defense Reutilization and Marketing Service in its role and responsibility for handling and disposing of the DoD's excess electronic equipment.

Technology Description

The Electronic Equipment Demanufacturing Recycling and Reuse System is an integrated system of eight (8) modules that processes electronic equipment into reusable or recyclable components. Typical equipment includes computers and monitors with cathode ray tubes (CRTs), radar devices, and communication devices. The modules are:

1. Receiving/Storage/Shipping—controls and accounts for each retired electronic equipment item as it flows into the demanufacturing facility as well as the recovered components, recyclable materials, and waste materials that flow out of the facility. Material tracking and accounting has become an important aspect of DoD modernization efforts to reduce costs, avoid waste, and minimize pollution.

2. Handling—controls the movement of material within the demanufacturing facility.

3. Disassembly—dismantles electronic equipment into more basic subassemblies or components that can be either recovered for reuse or further processed for materials recovery. Although disassembly can be performed using basic hand tools, more sophisticated disassembly techniques may be incorporated into the disassembly process to reduce labor costs.

4. Component Recovery—efficiently identifies and recovers critical components for reuse. Recovered components can be used to maintain the operational readiness of aging DoD systems that are plagued by parts shortages.

5. Testing—identifies equipment, subassemblies, and components that have reuse potential or may have marketable value in the commercial marketplace.

6. Glass Recovery—separates unleaded from leaded CRT glass and then prepares the CRT glass for reuse. Processed CRT glass is in the form of recyclable cullet, which can be used by CRT glass manufacturing facilities.

7. Metals Recovery—uses a more cost-effective and environmentally friendly process to separate metals and nonmetal materials from printed wiring boards. The process yields improved precious metal recovery at a lower processing cost to increase revenue.

8. Plastics Recovery—uses a novel processing system wherein engineering plastics are separated into high-purity concentrations of compatible types,

DoD Need

Reuse/recycle electronic materials

Service Need Numbers

Army: 3.5.c

Navy: 3.I.13.a

Typical electronic equipment includes computers, radar devices, and communication devices.

suitable as replacement for raw material. This process obtains the greatest possible value from the material, increasing revenues and minimizing a waste stream.

Technology Benefits and Advantages

- Reduces solid waste generation
- Accomplishes demilitarization while recovering valuable electronic parts that are needed to maintain DoD systems
- Removes hazardous components for proper disposal to avoid present and future liability
- Returns revenue to the military services
- Helps facilities to meet a DoD Pollution Prevention Measures of Merit mandate for 40% (wt.) landfill diversion by 2005

Technology Limitations

- System is still undergoing testing and has not been made commercially available.
- Facilities require appropriate pollution controls or regulatory permits.
- Output will be dependent on the composition of the input stream of retired electronic equipment.

NDCEE FY03 Accomplishments

- Conducted a Stakeholders meeting at the NDCEE Demanufacturing Technology Center in Largo, Florida, where all eight of the electronic equipment demanufacturing modules were demonstrated to the DoD and industry.
- Conducted validation testing of a pilot Electronic Equipment Demanufacturing and Recycling System, which the NDCEE assembled and installed in its Largo facility. Results from 76 tests showed that the scrap military electronics equipment was successfully processed to recover valuable electronic components for reuse and to generate recyclable glass, metal, and plastics.
- Initiated a technology transition of the demanufacturing technologies to LSAAP that included the transfer of all eight modules. The transition will be completed in FY04.
- Conducted hands-on training in the use and operation of the processes to LSAAP personnel.
- Prepared—as part of its technology transfer assistance—a Technology Transfer Package that contained a training course, equipment and operations manual, and pictorial record of the demonstration testing. The pictorial record consists of a compact disk with still photos and an approximately 30-minute video with voiceover that shows the process operating in real time, with close-up views on the working equipment.
- Produced a final report that summarizes all of the NDCEE's work in conjunction with assembling and validating a pilot Electronic Equipment Demanufacturing and Recycling System. System validation was conducted on two high-priority DoD waste streams, Federal Supply Group 58 and 59 items (e.g., radios, radar, and electronic components) as well as computer monitors with CRTs.
- Developed a multimedia presentation depicting the demanufacturing technologies that can be used by the DoD and industry.
- Developed a "Best Practices" CD ROM for use by the DRMS for the benefit of its field operations, the Defense Reutilization and Marketing Office (DRMO).
- Produced a logistic model for the DRMS for use in improving the DRMO logistics.
- Performed a hazards assessment of the DRMS top 100 National Stock Numbers.
- Produced a total of 20 information reports and two software programs and updated eight Technical Data Package/Operations and Maintenance manuals to reflect the latest technical information.

- Maintained the Demanufacturing of Electronic Equipment for Reuse and Recycling (DEER2) Web site (www.deer2.com), which is a repository of the most comprehensive compilation of electronics demanufacturing information that is currently available.

Economic Analysis

The DRMS is responsible for disposing of more than 30 million pounds of DoD electronic equipment annually. After examining DRMS practices and DRMS contractors, the NDCEE estimated that improved DEER2 methodologies and technologies have the potential to return $1 million per year to the Government in material recycling and component recovery fees. In addition, demanufacturing scrap electronic equipment can save approximately $400,000 in demilitarization annually. Finally, the DoD can avoid approximately $25 million annually in third-party site cleanups if electronic scrap disposal is properly managed. The reuse of components and systems that could be returned to the military or to commercial use is an additional savings that could be significant, but has not been quantified.

Suggested Implementation Applications

The Electronic Equipment Demanufacturing Recycling and Reuse System was designed for demanufacturing facilities to process electronic equipment into reusable or recyclable components.

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Applicable NDCEE Tasks

Demanufacturing of Electronic Equipment for Reuse and Recycling (Tasks N.228 and N.302)

Pilot Electronic Equipment Demanufacturing and Recycling Validation System (Task N.251)

ElectroSpark Deposition Micro-Welding Process

Using specimens provided by the Pacific Northwest National Laboratory (PNNL), Richland, Washington, the NDCEE evaluated, within limited screen testing, the feasibility of using the ElectroSpark Deposition (ESD) process to replace electroplated hard chromium (EHC) in non-line-of-sight (NLOS) applications. PNNL demonstrated the ESD process by coating 4340 steel flat and dog bone specimens with Stellite 21.

Technology Description

The ESD technology is a micro-welding process that uses very short duration, high-current electrical pulses to deposit electrode material on a metallic substrate. This emerging technology has been projected to be an alternative to the high-velocity oxy-fuel (HVOF) process that is gradually replacing EHC in some applications.

In contrast to most coatings that may produce chemical or mechanical bonds with a substrate, the ESD process creates a true metallurgical bond while maintaining the substrate at or near ambient temperatures. Research is in progress to develop the ESD process to coat non-line-of-sight applications and configurations, which include angles, crevices, and small inner diameters or insides of blind holes. This technique is potentially the next evolution in the process that will offer significant benefits over the currently available technology and one that will complement the existing HVOF alternative by coating geometries that are not possible using HVOF.

DoD Need

Alternative nonchromium plating method

Service Need Numbers

Army: 3.1.c, 3.10.f

Navy: 3.I.03.e

An ESD system is comprised of a capacitor-based power supply and an electrode holder (or applicator). Its function is to deposit a consumable electrode onto the substrate by means of electric sparks. When the capacitor energy is released, the direct current generates a plasma arc between the tip of the electrode and the substrate. At temperatures between 8,000-25,000°C, the plasma arc ionizes the consumable electrode and a small quantity of the electrode material is transferred onto the work piece to produce a robust, damage-resistant coating. The period of the high-energy pulse is extremely short relative to the interval period, so very little heat is transferred or accumulated to the substrate during each cycle. The low heat input to the substrate results in little or no heat-affected zone, distortion, pitting, shrinkage or internal stress.

Electrospark Deposition Process

Technology Benefits and Advantages

- Achieves surface builds and coating hardness and smoothness that are comparable to EHC used in non-line-of-sight applications
- Possesses fewer inherent environmental and worker safety risks than hard chromium electroplating
- Provides life-cycle performance and costs (including component rework and repair requirements) that are comparable to or better than EHC
- Provides wear performance that is similar to or better than EHC
- Maintains or improves production rate and/or part quality while minimizing maintenance requirements

Technology Limitations

The following limitations were determined based on the PNNL's demonstration and NDCEE screen testing results.

- Stellite 21 ESD-coated specimens did not exhibit consistent corrosion resistance and did not exhibit equal or better corrosion characteristics than the EHC-plated specimens in the Salt Spray Test.

- Because the ESD panels were not polished by PNNL, only limited wear resistance testing could be performed. Although a true comparison could not be made with the polished EHC panels, relative comparisons indicated that the ESD-coated specimens performed nearly as well as the ECH-plated specimens.
- Results from fatigue testing showed that the cycles to fracture of the ESD-coated specimens were somewhat less than that of AFRL's EHC specimens.

NDCEE FY03 Accomplishments

In accordance with its Screening Test Plan, the NDCEE conducted tests to evaluate ESD coatings on the 4340 steel substrate for corrosion resistance, wear resistance, and fatigue. Test results were documented in a Screen Test Report.

Economic Analysis

EHC represents a significant contribution to hazardous, carcinogenic waste generation and pollution control costs. Increasingly stringent OSHA and EPA regulations will continue to increase costs of hexavalent chromium processes. ESD shows cost-effective potential because substrates require no special surface preparation, and the process releases no hazardous wastes, fumes or effluents and requires no special chambers, spray booths or operator protection.

Suggested Implementation Applications

None at this time. The technology requires additional research and development.

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Applicable NDCEE Task

ElectroSpark Deposited Coatings for Replacement of Chrome Electroplating (Task N.253)

Facility Environmental Management and Monitoring System

Under previous efforts, the NDCEE successfully designed and implemented a Facility Environmental Management and Monitoring System (FEMMS) at Tobyhanna Army Depot. The system was tailored to meet TYAD's unique needs as the DoD's largest full-scale communications-electronics maintenance facility. The NDCEE leveraged these efforts to design and implement a FEMMS that addresses the specific monitoring and environmental needs of a munitions facility, Radford Army Ammunition Plant. Current efforts are focused on continuing to enhance the FEMMS as well as implementing other pollution prevention improvements at RFAAP.

Technology Description

FEMMS integrates environmental data, hardware (sensors, monitors, and alarms), and software into a single system for industrial and environmental operations. It provides analysts, managers, process personnel, and command-level staff with access to critical environmental information at near real-time speeds, thus providing quick response capabilities—all with off-the-shelf, commercially available technologies. As a result, FEMMS enhances productivity and environmental performance as well as reduces waste and cost while conserving valuable resources.

FEMMS is tailored to fit the needs of a facility. For instance, the TYAD FEMMS features monitoring/control systems for weather, drinking-water distribution and quality, steam plant emissions, road temperature, industrial wastewater treatment, sewage treatment, storm water, cold storage, hazardous materials and waste storage, and emergency power generation, as well as a centralized environmental information system with GIS and GPS capabilities.

The RFAAP FEMMS replaced unreliable equipment and labor-intensive manual methods and added new environmental monitoring capabilities, including early warning and alarm capabilities for corrective actions and emergency response. The system supports the activities of several independent, yet integrated, modules that connect 55 sites across the facility. The RFAAP FEMMS includes an Air Dispersion Modeling and Emergency Response System module, Selective Catalytic Reduction/Nitrogen Oxide (SCR/NO_x) Analyzer module, Virginia Pollutant Discharge Elimination System monitoring system for permitted outfalls to the New River, and monitoring system for ammonia tank farm pressures. In addition, the NDCEE is determining the system requirements, designing systems, and implementing monitoring control technologies for an acid concentration fume incinerator, audible notification systems for chemical releases, fossil-fuel energy generation opacity, and chemical recovery unit processes.

The NDCEE also is designing, developing, and installing a wireless Local Area Network (LAN) application to support RFAAP's nitrocellulose production, BioPlant line waste acid treatment, and SCR/NO_x areas. The LAN application includes the use of handheld devices for data entry, data retrieval, and reading bar codes. Paper forms are being converted into electronic formats to allow RFAAP operations personnel to manually enter data through the wireless handheld devices or through operations workstations available onsite.

DoD Need

Improved environmental monitoring and management of a facility's operations

Service Need Numbers

Air Force: 400-434, 900-2088

Army: 2.2.a, 2.2.f, 3.3.c

Navy: 2.I.02.a

An automated acid monitoring system was installed in RFAAP's acid area (in photo).

Technology Benefits and Advantages

- Provides real-time situational awareness and early warning to environmental process deviations
- Provides a global perspective on facility operations
- Reduces labor-intensive environmental activities
- Verifies conformance to environmental mandates

Technology Limitations

- Initial capital and labor costs for computer and sensor technologies are high, but costs that are associated with the lack of timely data and potential environmental fines are even greater.

NDCEE FY03 Accomplishments

- Developed a design package of the ammonia pressure control system for RFAAP, upgraded the system, and integrated pressure instruments.
- Developed and implemented a design package of RFAAP's SCR unit.
- Produced a Mass Balance Technical Report and a System Decision Report on RFAAP's ethanol mass balance and distillation column, redesigned the distillation column, and produced the Distillation Column Technical Report.
- Prepared a test plan on propellant biodegradation, conducted bench-scale testing, produced a pictorial record of the testing, and developed a System Decision Report.
- Produced a design package for a pilot-scale RFAAP security and surveillance module and developed a System Decision Report. Implementation of the facility security upgrade is planned for FY04.
- Determined process objectives and baseline requirements for a vertical integration module (the wireless LAN application). Implementation of the module is planned for FY04.
- Determined process objectives and baseline requirements for an Electrostatic Precipitators (ESPs) module. In FY04, a design will be produced for a modification or upgrade of RFAAP's Powerhouse five ESPs to improve their efficiency in removing particulate matter from the Powerhouse's boiler emissions.
- Began collecting data for an ECAM℠ assessment.

Economic Analysis

The NDCEE conducted an economic analysis on the FEMMS modules that are installed at TYAD. The following table contains the cost-benefit findings.

Module	Cost-Benefit Findings
Industrial Operations	IRR (15 years) = 21.4% Payback = 4.8 years
Weather	IRR (15 years) = 13.7% Payback = 7.0 years
Steam Plant	IRR (15 years) = 13.4% Payback = 7.0 years
Cold Storage	IRR (15 years) = 25.6% Payback = 4.2 years
Road Sensor	IRR (15 years) = 72.6% Payback = 1.2 years
Emergency Generator	IRR (15 years) = 63.3% Payback = 0.7 year
Drinking Water	IRR (15 years) = 16.2% Payback = 6.1 years
Storm Water System	IRR (15 years) = (7.0%) Payback = Not applicable
Sewage System	IRR (15 years) = 15.3% Payback = 6.3 years
HazMat Building	IRR (15 years) = 191.5% Payback = 0.5 year
HazWaste Building	IRR (15 years) = 91.3% Payback = 1.0 year

Suggested Implementation Applications

With the ability to monitor, compile, and model data from all aspects of facility operations, the technologies that are employed by FEMMS are applicable to potentially all DoD facilities.

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Applicable NDCEE Tasks

Managing Army Technologies for Environmental Enhancements (Tasks N.310 and N.315)

Fiber Media Blasting

Under previous efforts, the NDCEE and Naval Surface Warfare Center, Carderock Division tested several alternatives, including fiber media blasting, to current coatings removal and etching methods at the NDCEE Demonstration Facility and Norfolk Navy Shipyard. The NDCEE utilized these efforts to help identify potential alternatives to chemical or mechanical coatings removal processes for use on delicate substrates, many of which are also dimensionally critical parts. Fiber media blasting was found to be a technically and economically viable alternative for removing nonskid coatings from special hull treatment (SHT) tiles on LOS ANGELES (SSN 688) Class submarines.

Technology Description

Fiber media blasting offers a seamless method of surface preparation, cleaning, and decontamination of substrates. The media is a fiber-reinforced polymer matrix that is a composite of fiber, resin, polymer, and the desired surface treatment particles (plastic, cellulose, walnut, steel, or aluminum oxide). On average, this technology has a throughput of 400–600 pounds of media per hour and consumes 50–70 pounds of media per hour.

Three common types of fiber media are cleaning fiber medium, walnut fiber medium, and aluminum oxide fiber medium 30. The cleaning fiber medium consists of a no-profile, nonabrasive, cleaning medium. It is used for soft substrate cleaning, and grease and oil removal. It contains no abrasive content and is safe for rubber and plastic surfaces. The walnut fiber medium is also a no-profile-cleaning medium but uses walnut shells for low abrasive cleaning. This type of medium is typically used for coatings removal on sensitive substrates and equipment and is effective in cleaning harder surface contaminants. The aluminum oxide fiber medium 30 is the most aggressive medium available with a 3-plus mil profile. This medium is used for industrial coatings removal and decontamination.

The NDCEE has demonstrated an engineered media blaster that includes a media vibrator to ensure even flow rates for a wide range of media types, an air muffler for quieter depressurization, a pneumatic media flow valve for maximum control, a large manhole cover for easy clean out, and a large pop-up valve and inlet for fast charging. Other systems that are available for use with the media blaster are a vapor injection system and media classifier. The vapor injection system introduces pressurized vapor into the blast air stream to accelerate surface treatment operations, combine multiple surface preparations into one process, and dramatically reduce dust generation. Using a classifier, the media can be recycled anywhere from 5–15 times. The amount of times that the media can be recycled depends on the type of surface and contaminants that are being removed. Some features of the classifier include a waste screen that separates large debris and contaminants from the media, another screen to remove dust and consumed abrasives from reusable media, a rotational system to ensure an exact flow pattern to maximize production, and a motor access panel for easy maintenance.

Technology Benefits and Advantages

- Eliminates hazardous airborne particulates from blasting operations, decreases solid waste, and eliminates the use of chemical strippers
- Reduces labor and operating costs as a result of decreased pre-removal preparation and post-removal cleanup
- Improves safety and worker health conditions due to the elimination of airborne emissions of heavy metals and other contaminants when used with vacuum recovery

DoD Need

Environmentally preferred coatings removal technique

Service Need Numbers

Air Force: 100-202, 213, 221, 298; 200-304, 309, 327, 332; 900-2095; 1600-1646; 1700-1754

Army: 2.1.h, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

- Uses recyclable media
- Helps facilities to comply with Executive Order 13148, which requires the DoD to decrease the amount of waste that is generated at federal facilities, as well as environmental regulations regarding airborne particulate emissions

Technology Limitations

- Not as aggressive on metallic substrates as some, more abrasive media. However, unlike fiber media, abrasive media do not have the capability to be used on delicate substrates.

NDCEE FY03 Accomplishments

- Conducted field demonstrations on four coating removal processes on behalf of Fort Eustis and NAB Little Creek. Sponge, fiber, water, and wet sodium bicarbonate blasting were evaluated on their ability to meet the facilities' production requirements and waste reduction needs. They also were tested on some delicate substrates to determine if the substrates would be damaged during the coating removal process. Based on test results, the NDCEE recommended sponge and fiber media blasting for implementation at Fort Eustis and water or fiber media blasting for NAB Little Creek. Results were documented in a Technical Report.
- Produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on the NDCEE fiber media demonstration at NNSY and Naval Station Mayport in FY02. The fiber media blasting technology removed nonskid coatings from SHT at an average rate of 28 square feet per hour. As part of its technology evaluation, the NDCEE also conducted a cost-benefit analysis using the ECAM℠ tool to ensure environmental, safety, and health issues that are associated with the coating removal process were included. The fiber media technology was recommended for implementation to remove nonskid coatings from the steel submarine hull.

Economic Analysis

The NDCEE conducted a cost-benefit analysis in which it compared fiber media blasting to current removal methods for nonskid removal from SHT tiles. Capital costs for the fiber media blasting equipment are approximately $44,500. Annual operating costs are estimated to be $13,779. The operating costs for the dry abrasive blasting equipment is estimated to be $63,247. Pearl Harbor Naval Shipyard supplied the baseline data. Based on ECAM℠ results, the simple and discounted payback periods for the fiber media technology are less than one year. The NPV for each study period (5, 10, and 15 years) is positive ranging approximately $200,000–$600,000. The IRR values of 120–122% are acceptable to justify the investment.

The NDCEE also conducted a cost-benefit analysis using the baseline removal rate that was received from Ft. Eustis on its dry sodium bicarbonate blasting process for aluminum and fiberglass components. Test results show that the fiber media technology offers a comparable strip time to the baseline of 4–5 hours, causes no damage to delicate materials, and emits little to no dust. Because of the comparable strip rates, associated labor costs should be the same as the baseline method. Reduced procurement and disposal costs are anticipated because the fiber media are recyclable. Procurement savings are dependent on the price of the raw materials.

Suggested Implementation Applications

Fiber media blasting may be used on a variety of delicate substrates such as aluminum and

fiberglass. Applicable weapons system components include SHT tiles on submarines, fiberglass hoods on HMMWV, and potentially Navy and Air Force radomes.

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Applicable NDCEE Tasks

Pollution Prevention Initiative (Task N.227, Mod 1)

Sustainable Green Manufacturing (Task N.301, Subtask R3-10)

Fuel Cells

The NDCEE provided fuel cell assistance to the U.S. Army Engineer Research and Development Center/Construction Engineering Research Laboratory, which was assigned the mission of managing the Fuel Cell Demonstration Program for the DoD. The technical assistance was to evaluate and make recommendations that are relative to performance, emissions, reliability, operability, maintainability, and overall life-cycle costs of power plant systems and subsystem components. During FY99–FY00, the NDCEE designed and constructed the DoD Fuel Cell Test and Evaluation Center (FC*Tec*), Johnstown, Pennsylvania. The FC*Tec* mission is to significantly accelerate the development and commercialization of fuel cell power systems for military and commercial applications. The NDCEE also installed a 200-kilowatt (kW) PC25C Phosphoric Acid Fuel Cell Power Plant with customized capabilities, an AVISTA SR-12 modular proton exchange membrane generator, and testing equipment in the FC*Tec*.

Technology Description

Fuel cells generate electricity through an electrochemical process in which the energy that is stored in a fuel is converted directly into direct current (DC) electricity. Because electrical energy is generated without combusting fuel, fuel cells are extremely attractive from an environmental standpoint due to their low emissions and other factors. They can be used as stand-alone power sources for off-grid, remote sites, or as a backup power source to an on-grid site. Thermal output from the fuel cell can be used for heating boiler makeup water, space heating, condensate return, process hot water, etc.

DoD Need

Use of alternative or renewable energy sources to help facilities comply with the U.S. Energy Policy Act of 1992 and other federal, state, and military directives

Service Need Numbers

Army: 2.1.g

Navy: 2.I.01.b, 2.I.01.i

All fuel cells have the same basic operating principle. A fuel cell is a device that converts the energy of a fuel [hydrogen (H_2), natural gas, methanol, gasoline, etc.] and an oxidant (air or oxygen) into useable electricity. Fuel cell construction generally consists of a fuel electrode (anode) and an oxidant electrode (cathode) that is separated by an ion conducting membrane. The input fuel passes over the anode (and oxygen over the cathode) where it splits into ions and electrons. The electrons pass through an external circuit to serve an electric load while the ions move through the electrolyte toward the oppositely charged electrode. At the electrode, ions combine to create by-products, primarily water and carbon dioxide. Depending on the input fuel and electrolyte, different chemical reactions will occur.

The four primary types of fuel cells (their names correspond to the electrolyte employed) are phosphoric acid, molten carbonate, solid oxide, and proton exchange membrane. A comparison of the fuel cell types is summarized in the table (below).

Fuel cells are typically grouped into three sections: fuel processor, power section, and power conditioner. In the fuel processor, a fuel, such as natural gas, is reformed to chemically extract the hydrogen atom from the host fuel. The hydrogen-rich fuel and

Feature Comparisons Among Fuel Cell Applications

	Phosphoric Acid	Molten Carbonate	Solid Oxide	Proton Exchange Membrane
Electrolyte	Phosphoric Acid	Molten Carbonate Salt	Ceramic	Polymer
Operating Temperature	375°F (190°C)	1200°F (650°C)	1830°F (1000°C)	175°F (80°C)
Fuels	H_2 Reformate	H_2/CO/ Reformate	H_2/CO_2/CH_4 Reformate	H_2 Reformate
Reforming	External	External/Internal	External/Internal	External
Oxidant	O_2/Air	CO_2/O_2/Air	O_2/Air	O_2/Air
Efficiency (HHV)	40–50%	50–60%	45–55%	40–50%

oxygen (air) then feeds into the power section to produce DC electricity and reusable heat. This section includes a fuel cell stack, which is a series of electrode plates interconnected to produce a set quantity of electrical power. The output DC electricity is converted to alternating current electricity in the power conditioner.

Technology Benefits and Advantages

- Use of alternative or renewable energy sources helps facilities comply with the U.S. Energy Policy Act of 1992 and other federal, state, and military directives
- Improved energy conservation and reduced environmental impacts in comparison to traditional energy sources
- High-energy conversion efficiency, fuel flexibility, and cogeneration capability
- Modular design with no moving parts
- Very low chemical and acoustical pollution
- Rapid load response
- Simple installation, no specialized fuel cell experience needed

Technology Limitations

- Initial equipment costs may be high, but are improving as the technology becomes more widely disseminated.
- As with any new and advanced power technology, fuel cells involve design and construction planning as well as additional maintenance training.
- Distributed power sources require dedicated onsite space requirements.
- Caution must be exercised since high voltages are a potential danger.

Economic Analysis

For a United Technologies Company fuel cell, 200-kW PC25C, the NDCEE determined that the average cost for a typical installation excluding any geographic cost index adjustments for labor should be in the $90,000–$100,000 range. Any nontypical or auxiliary equipment will be in addition to the base installation cost. The installation costs for some of the military fleet have been recorded and tabulated to allow review of installation options, interface requirements, and installation cost. These initial fuel cell systems cost an average of $110,000, with a minimum cost of $84,000 and a maximum cost of $200,000.

Fan Skid

NDCEE FY03 Accomplishments

- Completed all testing and evaluation on the UTC Fuel Cell PC25C
- Completed fuel cell test protocol for residential sized fuel cell systems
- Completed testing on the 5kW Plug Power PEM fuel cell system
- Prepared and submitted the Final Report

Suggested Implementation Applications

Fuel cells may be used by any site that requires a power source and are particularly useful for remote, off-grid sites. The DoD Fuel Cell Demonstration Program sites represent a broad spectrum of facilities and locations throughout the Services.

High-Power Thermal Load Bank

Points of Contact

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Applicable NDCEE Task

U.S. Army ERDC/CERL Fuel Cell Technology Program (Task N.211)

Handheld Corrosion Data Collection System

The NDCEE is developing a fully functional corrosion data collection system for U.S. Army facilities. As part of its efforts, the NDCEE has designed and implemented data entry software for use on commercially available personal digital assistants (PDAs). The system has been field-tested at five Army facilities.

Technology Description

The handheld corrosion data collection system allows field technicians to easily collect and transfer corrosion data to a database. The facility can use the database to efficiently detect the onset of corrosion-related maintenance issues of its vehicles and weapon systems. As a result, facilities will be able to conduct condition-based maintenance, including preventive maintenance, and thereby reduce life-cycle costs.

The collection device is a lightweight, user-friendly PDA with data entry software that provides an easy-to-use platform for entering and storing data. The user interface is Microsoft® Windows® CE that runs an embedded Visual Basic program. The program contains part lists that are accessible through drop-down menus. These lists are used to simplify data entry and provide uniform data collection standards for all users. Once the user has gathered the appropriate data, the data can be transferred into the corrosion database via PalmSource, Inc.'s HotSync™ and the Internet. The database is accessible to networked workstations or the Internet via Web pages.

The NDCEE has performed field tests of the system that was implemented on a Hewlett Packard 540 Jornada (PDA). The test locations were Fort Bragg, Fort Eustis, Fort Hood, Fort Lewis, and Fort Story. The tests were used to evaluate and validate the proof-of-concept. Efforts are underway to populate site-specific corrosion databases.

DoD Need

Corrosion detection and prevention in tactical vehicles and equipment

Technology Benefits and Advantages

- Improves efficiency and accuracy while recording data
- Utilizes low-cost, commercially available PDAs that are lightweight, easy to use, and programmable (which gives the PDA the versatility to add to its functionality, such as the ability to display procedures and environmental cleanup hazards)
- Easily transfers data collected by the PDA to the corrosion database
- Can communicate with other computers that are running Windows operating systems
- May potentially support digital photos, remote transfer of data, and other advances in PDA technology

This handheld corrosion data collection system allows field technicians to easily collect and transfer corrosion data to a database.

Technology Limitations

- Proper care is required to prevent the handheld PDA from being damaged.
- PDAs have a short battery life (3–4.5 hours with continuous use).
- The screen on some units is difficult to see in bright sunlight.

Economic Analysis

The NDCEE has not presently conducted a cost-benefit analysis. However, the data collection system is expected to greatly decrease a facility's corrosion-related expenses.

The typical cost for a PDA ranges $400–$800, depending on the unit and optional attachments.

NDCEE FY03 Accomplishments

The NDCEE transitioned a handheld corrosion device to Fort Shafter. In FY01, the NDCEE designed and implemented data entry software for use on PDAs, and then evaluated and validated the system's proof-of-concept during site visits to Fort Bragg, Fort Eustis, and Fort Story. In FY02, the NDCEE collected real-time data to populate the corrosion database during additional site visits to Fort Bragg, Fort Eustis, Fort Hood, Fort Lewis, and Fort Story.

Suggested Implementation Applications

The NDCEE is currently collecting data on heavy equipment machinery and the M939 5-ton truck. However, the corrosion data collection system is available for use for any DoD application in which data recording is required to improve accuracy and efficiency. Typical locations include motor pools and other maintenance facilities.

Points of Contact

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Applicable NDCEE Tasks

Corrosion Measurement and Control Program (Tasks N.255 and N.304)

Ion Implantation Process

The NDCEE has demonstrated and evaluated the feasibility of using ion implantation systems to deposit various metals on Inconel 718 and 4340 steel substrates. The NDCEE has determined that the process is a viable enhancement of EHC and can be used to extend the service life of the original component (with or without EHC).

Technology Description

Ion implantation is a surface modification process in which ions are injected into the near-surface region of a substrate. High-energy ions, typically 10–200 kiloelectron volts in energy, are produced in an accelerator and directed as a beam onto the surface of the substrate. The ions impinge on the substrate with kinetic energies 4–5 orders of magnitude greater than the binding energy of the solid substrate and form an alloy with the surface upon impact. Virtually any element can be injected into the near-surface region of any solid substrate. Commonly implanted substrates include metals, ceramics, and polymers. The most commonly implanted metals include steels, titanium alloys, and some refractory metals.

During the ion implantation process, a beam of positively charged ions of the desired element (either a gas such as nitrogen or a metal such as boron) is formed. Beam formation of a gas occurs by feeding the gas into an ion source. In the ion source, electrons, emitted from a hot filament, ionize the gas to form plasma. Ionization of the element is performed for the purpose of acceleration. Incorporation of an electrostatic field results in the acceleration of the positive ions at high energies under high vacuum (pressures below 10^{-5} Torr). The ions penetrate the component surface, typically to a depth not exceeding 0.1 μm. The near-surface alloy that is produced by implantation is different from conventional coatings in that the implanted ion is surrounded by atoms of the original surface material. Alloying at the surface can be as high as 50 atomic percent of the implanted element. It produces no discrete coating, nor will delamination of the altered surface occur.

DoD Need

Environmentally preferred surface protection and control

Service Need Numbers

Air Force: 1600-1625

Army: 3.1.c

Navy: 2.I.01.g, 3.I.03.e, 3.I.04.h

Forming a beam of a solid element can occur by one of four methods. The first method is commonly used in the semiconductor industry, which requires extremely high-purity beams. In this method, a reactive gas, such as chlorine, is used to form the plasma. A metal chloride is generated as the chlorine ions chemically react with the metal walls of the ion source. The metal chloride then is ionized to form plasma of metal and chlorine ions. An analyzing magnet is used to separate the chlorine ions from the desired metal ion beam.

Located in the NDCEE Demonstration Facility, this technology has both ion implantation and ion beam assisted deposition capabilities.

The second method employs sputtering to generate metal ions. In this method, inert argon gas is ionized. The positively charged ions are attracted to a negatively biased metal target. As the argon ions strike the target, pure metal atoms and ions are dislodged from the target. The metal ions are extracted, focused into a beam, and directed toward the part to be implanted. The two other methods of forming a beam of a solid are similar to that of the sputtering method. Variations of the sputtering method use thermal or electron beam evaporation, or cathodic arc (initiating an arc on the surface of a metal target to evaporate the metal) to generate the metal vapors. These methods do not require the costly analyzing magnets and provide very high ion currents.

A newer form of ion implantation involves using plasma within the chamber from which gaseous ions are extracted. Similar to the beamline method, the gas is excited to form plasma, typically through the use of an RF antenna. The positively charged gas ions are accelerated towards the substrate by subjecting the substrate to high voltage pulsed potential. This method of implantation is referred to as plasma source ion implantation (PSII) and circumvents some of the line-of-sight issues associated with conventional beamline methods.

Possible products of this process are the formation of nitrides, borides, or carbides, or the occurrence of localized alloying. With this process, properties such as hardness, wear resistance, corrosion resistance, and fatigue may be altered according to the selected implantation element. Ion implantation can provide 2–100-fold improvements in wear life, depending on the type of wear and service environment.

Technology Benefits and Advantages

- Can reduce the use of hexavalent chromium, leading to reductions in environment, health and safety costs
- Reduces operational costs and labor requirements as a result of reducing the use of hazardous materials and the associated compliance procedures/processes
- Reduces operator exposure to hexavalent chromium
- Reduces waste generation
- Extends wear life of original components and reduces maintenance costs

Technology Limitations

- High capital costs (in the range of $500,000+, depending on size and process type)
- Extensive training required for operators
- Line-of-sight limitations
- Longer operating times than other processes
- Limitations of surface area that can be treated

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with demonstrating selected EHC alternatives, including ion implantation. Activities included:

- Producing a Demonstration Plan that outlined the activities that were necessary to demonstrate selected EHC alternatives, including ion implantation, and the test methods and procedures that were used to evaluate the coatings and surface modifications. The alternatives were identified in a FY00 Potential Alternatives Report for Ion Beam and Plasma-Based Alternatives to Chrome Plating of Gas Turbine Engine Parts.
- Demonstrating the feasibility of using the ion implantation process to implant various materials for DoD propulsion applications. Chromium, titanium, and titanium/nickel were implanted into 4340 steel substrates. Aluminum, phosphorous, titanium/nickel, tantalum, and chromium were implanted into Inconel 718 steel substrates. 4340 steel and Inconel 718 are two of the most prevalent materials in a gas turbine engine. The demonstrations were performed at vendor facilities.
- Performing corrosion, wear, adhesion, and nanohardness tests on implants in accordance with the NDCEE Demonstration Plan to screen alternative coatings.
- Producing a Demonstration Report that documented the results of the demonstration/validation activities to determine the effectiveness of ion implantation. The results showed that the alternative process offered wear performance improvements when compared to EHC.

- Performing an ECAM℠ analysis to evaluate the cost benefit of utilizing nitrogen ion implantation to modify the surface of EHC components.
- Producing a Justification Report that documented the technical justification of the alternatives that are recommended for further investigation.

Economic Analysis

In FY02, the NDCEE conducted an ECAM℠ analysis in which the EHC plating process at Anniston Army Depot was compared to EHC with supplemental ion implantation via beamline ion implantation for intermediate bearing housings and also via PSII. In general, the processing costs of the two methods were determined to be more expensive than EHC costs, but they provide an extended life to each component due to improved engineering properties. This extended wear life makes implementing ion implantation economically feasible, as noted below in the payback periods for each process. Also, the reduction in rework lowers the exposure to EHC, which represents a significant contribution to hazardous, carcinogenic waste generation, and pollution control costs.

The ECAM℠ considered service improvements with the PSII and ion implantation processes at a twofold, three-fold, and five-fold extended wear life. Wear performance improvements would be expected to increase part service life—the maintenance to rebuild worn parts, restore dimensional tolerance, and replace a worn or damaged coating such as hexavalent chromium would occur less frequently. Extended service life can lead to a decrease in total cost-of-ownership through engine overhaul cycle and labor hours and improved weapons system readiness. The ECAM℠ did not consider any environmental, health, or safety savings. The reduced costs of waste disposal and regulatory compliance that are associated with hard chromium would add a cost savings to the analysis.

Using a 15-year analysis with a 3.2% discount rate on a five-fold extended service life, ECAM℠ results showed a payback period of 3.6 years, an NPV of $2,341,000, and a 32.8% IRR for PSII. Conversely, for beamline ion implantation, the results showed a payback period of nearly 11 years, an NPV of $806,000, and a 9.8% IRR. These finding reflects purely operational costs and should only be used as a guideline in understanding the cost differences in ion beam processes and EHC plating. The cost that was determined from the process data for EHC is $17.80 per square inch ($2.76 per square centimeter). PSII incurs an additional cost of $7.61 per square inch ($1.18 per square centimeter), while ion implantation incurs an additional cost of $44.90 per square inch ($6.96 per square centimeter).

Suggested Implementation Applications

Ion implantation is a potential enhancement method for chrome plating or other plating processes as well as a process that can improve engineering properties of substrate materials. Therefore, any site using electrolytic hard chrome plating or other plating processes could be a candidate for implementation, as could original equipment manufacturers to improve the service life of components such that refurbishment would not be necessary until a much longer service period has passed.

Points of Contact

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Applicable NDCEE Task

Pollution Prevention Initiative (Task N.227)

Lactate Ester Cleaning Technology for Weapon Systems

The NDCEE demonstrated and evaluated the feasibility of using lactate esters as both a depainting and cleaning technology. Demonstration findings revealed that the technology is presently suitable as a cleaning alternative, but while results are promising, the technology is not currently suitable as a depainting alternative. The NDCEE implemented a lactate ester cleaning process at Anniston Army Depot in 2002 for cleaning applications.

Technology Description

From both a technical and economic perspective, lactate esters have been proven to be a viable alternative to P-D-680A Type II cleaner, commonly used in immersion and small-component spray (parts washers) equipment. They are not ideal replacements for blasting processes, which are quick, capable of recycling, and relatively inexpensive. The lactate esters that were evaluated by the NDCEE did not perform well on the specific depainting applications attempted. Therefore, additional reformulation and evaluations are recommended.

Made from cornstarch or sugar, lactate esters are nontoxic, biodegradable materials with excellent solvent properties. Ethyl lactate is the ethyl ester of natural lactic acid. It is a clear, colorless, low-volatility liquid that is miscible with water and most organic solvents, has a low vapor pressure of 1.7 millimeters of mercury at 68°F (20°C) and a boiling point of 309°F (153.8°C). Ethyl lactate is commonly used in the food industry as a synthetic flavoring for cheese and animal feed. It is frequently combined in various proportions with methyl soyate or soy methyl ester (a solvent produced from soybeans) to obtain an increased flash point from 139°F (59.4°C) for pure ethyl lactate to greater than 150°F (65.6°C) for a blend. Blending with methyl soyate also suppresses the pungent odor characteristic of pure ethyl lactate.

On behalf of ANAD and other maintenance depots, the NDCEE evaluated the performance of three alternative blends by Vertec Biosolvents, LLC as cleaners: 50% ethyl lactate (EL) and 50% methyl soyate (MS), 70 EL/30 MS, and 30 EL/70 MS. These blends, as well as VERTEC™ Gold Paint Stripper, also were evaluated for their depainting capabilities. The lactate esters performed well as cleaners, ranging from 91–98% cleaning efficiency. These results compare favorably with that of P-D-680A Type II, a solvent widely used across the DoD as a degreaser to remove lubricants, oils, carbon deposits, and other surface particulates and contaminants from aircraft and ground combat vehicle components. Based on the results of the demonstration activities and vendor recommendations, ANAD selected the 30/70 blend for implementation. Two primary benefits of this blend are its higher flash point and more pleasant odor than the other blends.

Technology Benefits and Advantages

- Are nontoxic, biodegradable materials
- Produces results comparable to cleaners currently in use at DoD facilities
- Reduces or eliminates the generation of hazardous waste and release of hazardous materials into the environment
- Are compatible with most metal substrates
- Reduces worker health and safety risks by reducing or eliminating exposure to hazardous material usage
- Maintains or reduces the costs of cleaning operations
- Meets current and impending regulations

DoD Need

Environmentally compliant cleaning methods

Service Need Numbers

Air Force: 100-203; 200-287, 291; 1200-1271, 1287

Army: 2.1.h, 3.2.j

Navy: 2.I.01.g

Anniston Army Depot has implemented a lactate esters bath to clean ground combat vehicle components, such as bearings, springs, housings and gears, from engines and transmissions.

Technology Limitations

- Not presently suitable as paint strippers
- Not for use with polymeric materials and polyimide wire

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with evaluating the feasibility of using lactate esters as both a depainting and cleaning technology. These activities included:

- Producing a Requirements Report. The report identified the evaluation, testing, and justification requirements that were needed to evaluate alternative cleaning and depainting processes. Baseline information was obtained during site visits at ANAD, Corpus Christi Army Depot, and Marine Corps Logistics Base, Yermo Annex.
- Producing an Alternatives Report that described the criteria that were used for selecting alternative cleaning and depainting lactate ester technologies and described the alternative technologies.
- Producing a Demonstration Plan that outlined bench-scale testing activities.
- Conducting performance and mechanical testing at qualified laboratories using the three selected lactate ester blends and two baseline materials. The mechanical evaluations included such tests as corrosion, adhesion, hydrogen embrittlement, refinishing properties, and compatibility with metals, polymers, and polyimide wire. The results of this testing were summarized in the Demonstration Report.
- Producing a Justification Report that discussed the results of an economic analysis. Both the technical and economic results were favorable for cleaning applications.
- Conducting a full-scale demonstration at the NDCEE Demonstration Facility prior to equipment installation at ANAD. The 30 EL/70 MS blend was installed for cleaning into the transmission shop at ANAD.

Economic Analysis

The NDCEE conducted an economic analysis on two scenarios using the ECAM^{SM} tool, ANAD baseline data, and demonstration results. Scenario 1 considered using lactate esters for 6 months as a drop-in replacement. Annual operating cost savings were approximately \$44,800 with a discounted payback period of less than 3 months. This scenario had capital costs of \$9,550, which represented the purchase of five rinse tanks (\$1,200 each) equipped with belt oil skimmers (\$370 each) and \$1,700 for refurbishment of existing vats for solvent compatibility. The 15-year NPV is projected to be \$514,000. Scenario 2 included the installation of a parts washer equipped with filtration, providing a 12-month bath life. Annual operating cost savings were \$83,000 with a discounted payback period of approximately 19 months. Capital costs were \$130,139, which represented the purchase of nine 200-gallon parts washers (\$8,961 each), eight 80-gallon parts washers (\$5,205 each), and five rinse tanks (\$1,200 each) equipped with belt oil skimmers (\$370 each). The 15-year NPV is projected to be \$839,800; the IRR is 64%.

Suggested Implementation Applications

This technology will benefit DoD sustainment facilities that clean weapon systems and components, particularly those that use immersion and small-component spray equipment. The NDCEE demonstrated the use of the 30/70 blend at ANAD on transmissions from the M88A1 and M113 tanks. Other potential transmissions that are maintained at ANAD are from the Light Armored Vehicle, Amphibious Assault Vehicle, M1, M60, and M9 Armored Combat Earthmover.

Points of Contact

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Applicable NDCEE Task

Pollution Prevention Initiative (Task N.227, Mod 1)

Laser Decoating

The NDCEE has extensive technical expertise with coatings removal using laser decoating technologies. For instance, the NDCEE has evaluated the applicability of the FLASHJET® process for the removal of coatings from submarines and surface ships as well as on flight-critical status helicopter rotor blades. The NDCEE is currently tasked to evaluate four laser decoating systems on their ability to remove coatings from NAVSEA radomes. In FY04, the NDCEE will support Naval Surface Warfare Center, Carderock Division in conducting field demonstrations at three sites: a vendor site, Hill AFB, and Wright-Patterson AFB.

Technology Description

Laser decoating is a nonintrusive, nonkinetic energy process for removing organic coatings from a variety of substrates, including composites, glass, metal, and plastics. A laser, which is an acronym that stands for Light Amplification by Stimulated Emission of Radiation, is a device that generates monochromatic, coherent light that can be focused and concentrated into a narrow, intense beam of energy. This energy beam can be applied to coatings removal operations due to its ability to ablate a coating from a substrate.

The high-level energy from a laser beam is absorbed at the surface of a coating material, resulting in the subsequent decomposition and removal of that coating. As the coating is volatilized, decomposition by-products are thrown into the laser beam and incinerated to produce carbon dioxide, water, inorganic pigment ash, and trace amounts of other compounds. The organic constituents are exhausted into the atmosphere, and particulate matter is collected in conventional filters for future disposal. Because of this action, the amount of waste to be disposed of represents a fraction of the original coating volume.

The optical output from a laser may take the form of a continuous wave or a pulsed beam. Continuous wave lasers reflect photons so that the number of stimulated emissions equals the number of photons in the optical output. Pulsed lasers use various methods to output photons in surges instead of continuously. Both pulsed and continuous beam outputs have been proven effective for coatings removal applications.

Four main categories of lasers are used for coatings removal applications: solid-state, gas, excimer, and semiconductor. These categories are based upon the medium that is used to create the laser output. Solid-state lasers have material that is distributed in a solid matrix such as ruby or neodymium:yttrium-aluminum garnet (Nd:YAG) lasers. Gas lasers commonly use CO_2, helium, helium-neon, or argon as the medium. Excimer lasers use reactive gases, such as chlorine and fluorine, mixed with inert gases such as argon, krypton, or xenon. Semiconductor lasers are commonly called diode lasers and are contained on a small wafer of semiconductor material, such as gallium arsenide, that is less than a millimeter thick. This wafer produces a laser when an electrical charge is applied. Each of these types of lasers has unique characteristics that must be considered when selecting the laser type for a coatings removal application.

A typical laser coatings removal system consists of a laser, a beam delivery system, a manipulation system, and a waste management system. The laser beam delivery system is used to transfer the laser output to the work surface with the appropriate spot size and shape for delivering the energy density that is required for efficient coating removal. A manipulation system controls the position of the laser as it moves over the substrate surface, and the waste management system captures the particulate residue that is created by the ablation process. Another possible addition to the laser system is a feedback control system that allows the selective removal of primers, paints, topcoats, sealants, and other surface coatings.

DoD Need

Environmentally compliant paint removal method

Service Need Numbers

Air Force: 100-202, 213, 298; 200-300, 304, 309, 322, 332; 800-814; 900-2095; 1600-1646; 1700-1754

Army: 2.1.h, 2.3.k, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

Previous materials testing that was conducted by the NDCEE has shown that laser decoating technology was effective at removing even the most difficult coatings, including powder coats, electrocoats, chemical agent resistant coatings, and specialty coatings such as Rockhard stoving enamel. Removal rates varied between 5.8 and 17.5 ft^2/hr (250-W system) and 46 and 140 ft^2/hr (200-kW system) during this testing.

Technology Benefits and Advantages

- Is available as either hand-held or robotic system
- Is capable of selective stripping
- Reduces environmental impact from elimination of the use of hazardous chemicals and reduction of solid waste generated for disposal
- Reduces health and safety risks due to the elimination of exposure to hazardous chemicals and decoating residues
- Decreases operating costs due to reduced labor, materials use, damaged parts, and waste disposal costs
- Is applicable for removing organic coatings from composites, plastics, fiberglass, and metals

Technology Limitations

- Operator training required
- Line-of-site technology (although it can strip moderately contoured parts – up to approximately a 45-degree angle)
- High capital investment (starting at ~$500,000) associated with the robotic system

NDCEE FY03 Accomplishments

The NDCEE produced the Test Plan for Radomes and Antennas, which outlines how NSWC-CD and the NDCEE will test and evaluate the four laser coatings removal systems as an alternative coatings removal process for NAVSEA radomes and antennas. The test protocol provides technical information on the demonstration activities, substrate materials, process parameters, and acceptance criteria that will be used in the evaluation planned for FY04. The four laser decoating systems are: 2 kW semi-conductor automated pulsed diode laser system, 1.2 KW automated pulsed CO_2 laser system, a 40-W hand-held Nd:YAG laser system, and a 120-W hand-held Nd:YAG laser system.

Economic Analysis

The estimated capital cost for a laser decoating system for depot-level maintenance activities varies from $100,000 for a hand-held system to between $500,000 and $1.5 million for a robotic system.

Suggested Implementation Applications

Laser coating removal systems can potentially be used by any DoD sustainment facility that uses manual, hand sanding, abrasive blasting, and hazardous chemicals to remove coatings from metallic and composite substrates that are found on aircraft, surface ships, and submarines. For instance, a robotic CO_2 laser system is currently being utilized to remove coatings for Air Force and NAVAIR radomes at Hill AFB.

Points of Contact

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Applicable NDCEE Task

Coatings Removal from Delicate Substrates and Application Process Improvements for Department of Defense (DoD) Industrial Facilities (Task N.308)

Laser-Induced Surface Improvements Process

The NDCEE demonstrated and evaluated the ability of the Laser-Induced Surface Improvements (LISI℠) Process to apply a metal coating on two base metals. More specifically, a fatigue evaluation was conducted on 4340 steel substrates, chosen as representative of steels that are used in landing gear manufacturing. A corrosion resistance and shielding/grounding evaluation was conducted on 6061 aluminum substrates, an alloy used in the Mark 46 optical sight director.

Technology Description

The LISI℠ process is a controlled surface modification technique that is designed to tailor component surfaces to meet challenges such as corrosion or wear. The process begins by spraying an alloy precursor onto the substrate. Next, using a high-energy laser as the heat source, the precursor and the substrate are melted to form a new surface. The linear processing rate is 50–200 feet per hour, depending on the geometry of the part. The surface is modified from a depth of microns to 1 millimeter per single pass, depending on the substrate, precursor materials, and laser settings such as power, traverse rate, and focus.

Precursors play a vital role in obtaining desired properties such as wear and/or corrosion resistance. In addition, laser coupling changes with the precursor/substrate combination. As a result, process settings must be modified whenever the material changes. Coupling is generally increased as wavelength decreases, so this type of treatment is likely to be more successful with diode lasers than with carbon dioxide or YaG lasers.

LISI℠ is a new technology with limited data available. The theory is that because the surface composition is modified by alloying that occurs in part of the base metal, corrosion resistance is increased and surface adhesion problems do not occur. NDCEE demonstration results confirm that the precursor that is chosen determines corrosion resistance. In addition, the process may improve fatigue properties, but not for high-strength steels such as 4340, most likely because of their high ability to harden.

Technology Benefits and Advantages

- Produces little gaseous effluents and minimal hazardous waste streams due to nontoxic process
- Reduces or eliminates the use of hexavalent chromium (a known human carcinogen), leading to improved working conditions and reductions in EHS costs
- Reduces the operational costs and labor requirements as a result of eliminating hazardous materials and the associated compliance procedures/processes
- Extends wear life of original components and reduces maintenance costs
- Involves portable equipment, potentially enabling future in-field operation

Technology Limitations

- Laser treatment of high-strength steel is detrimental to fatigue performance.
- Process is currently limited to inner diameters greater than 2 inches and surfaces with no sharp corners or inner radius.
- Laser processing of some difficult-to-process materials such as high-strength steels will likely involve post-processing operations,

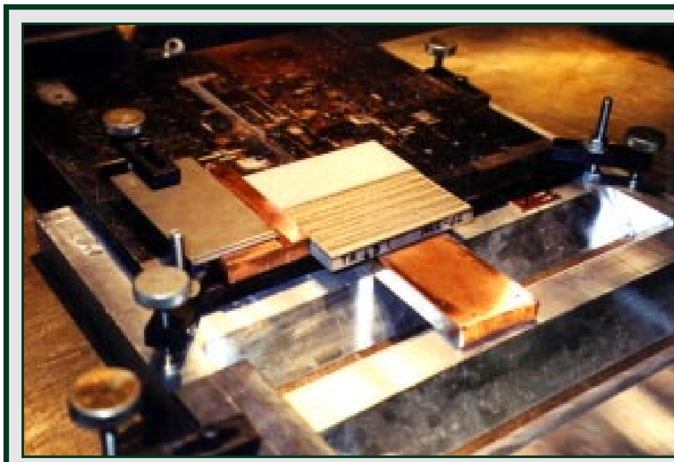
DoD Need

Environmentally preferred surface protection and corrosion control

Service Need Numbers

Army: 3.1.c

Navy: 2.I.01.g, 3.I.03.e, 3.I.04.h



Process setup showing high-strength steel slab approximately half way through LISI℠ treatment

such as heat treatments to restore components to desired hardness levels or peening operations to impart beneficial compressive residual stresses.
- Laser-processed components currently require final machining/honing to achieve desired surface finish due to the relatively rough surfaces produced by the laser.
- Limited data are available on the LISI^{SM} process because it is a new technology.

NDCEE FY03 Accomplishments
The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with evaluating the ability of the LISI^{SM} process to apply a metal coating onto a base metal. These activities included:

- Producing a Demonstration Plan that outlined the activities that are necessary to demonstrate select electrolytic hard chrome alternatives, including LISI^{SM}, and the test methods and procedures that are used to evaluate the coatings and surface modifications. LISI^{SM} had been identified in an FY00 Potential Alternatives Report for Ion Beam and Plasma-Based Alternatives to Chrome Plating of Gas Turbine Engine Parts.
- Demonstrating the feasibility of using the LISI^{SM} process to apply chromium/ chromium diboride, nickel/chromium, iron/vanadium, and iron/tungsten on 4340 steel substrates, and nickel/copper and nickel/boron on an aluminum 6061 substrate. The demonstration was performed at a vendor facility.
- Performing corrosion, wear, adhesion, and nanohardness tests on deposited coatings in accordance with an NDCEE Demonstration Plan to screen alternative coatings. A Demonstration Report was produced that documented the results of the LISI^{SM} demonstration/validation activities. While the LISI^{SM} process could provide the appropriate shielding/grounding properties, it could not consistently meet the corrosion requirements. In addition, laser treatment of high-strength steel was found to be detrimental to fatigue properties.
- Producing a Justification Report that documented the technical justification of the EHC alternatives that are recommended for further investigation. LISI^{SM} was not recommended.

Economic Analysis
LISI^{SM} has shown enough promise that, if combined with significant cost savings compared to current processes, further research and development may be in the Government's interest. At present, the operating costs per square foot for the hard chrome plating process of propeller hubs is estimated to be approximately $6. Cost data were obtained from NADEP-Cherry Point by the NDCEE under a previous effort. The operating costs for the LISI^{SM} process is estimated to be $143; however, further maturation of the process is expected to reduce costs to approximately $27 per square foot (i.e., approximately four times as expensive as EHC plating). Such a high process cost could only be justified through higher performance levels, which was not the case for the samples that were considered in the NDCEE studies, or through significantly lower EHS costs, which is currently not expected. However, a direct comparison of the costs between the two processes can only be performed upon scale-up of the laser-based surface modification process.

Suggested Implementation Applications
None at this time. The technology requires additional research and development.

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Applicable NDCEE Task
Pollution Prevention Initiative (Task N.227)

Magnetically Assisted Impaction Mixing

The NDCEE, in conjunction with researchers at the New Jersey Institute of Technology, is researching environmentally friendly technologies and processes to produce new materials and recycle both new and old materials (including composites and ceramics). As part of this effort, the NDCEE team is investigating three critical technical issues: (1) research on mixing of nano-sized particles, including the ability to scale-up; (2) evaluation of mixing effectiveness of any mixing process; and (3) consideration of environmental impact of the mixing processes. The main technical objective is to investigate techniques that can effectively mix two nano-constituents, with the eventual objective of using the technique for mixing metastable interstitial composites (MIC), mixtures of metal and metal oxides. These composites are alternatives to conventional lead-based primers for bullets/ ammunition and other potential applications.

Technology Description

Magnetically Assisted Impaction Mixing (MAIM) is being developed to improve the effectiveness of mixing powders with nano-sized particles without the aid of a solvent or heat. In general, uniform mixing of nano-sized materials is more difficult than mixing of larger-sized materials. Still in development, the technology will aid manufacturing applications in producing higher quality products. It is being developed in response to the DoD need for a safe and cost-effective approach to producing MIC as well as a variety of other applications involving nano- as well as sub-micron particles. Current methods of mixing MIC involve the use of solvents that contain VOCs, and the methods are not scalable for large-scale production.

With MAIM, small magnetic media (such as 1–2 mm ground magnets that are coated with polymer) are added to materials to be mixed, such as dry particulate material. When a variable magnetic field is applied, the magnetic media move to produce a mixing situation that is somewhat comparable to a fluidized bed in which the other material is mixed in a timely and energy-efficient manner. At the end of the mixing process, the field is turned off and the magnetic media can be readily removed.

Apart from the mixing of particles from 1–2 microns down to nano-size in various energetic formulations, the technology has other possible applications such as facilitating coating of particles to change performance characteristics and producing products with longer shelf life. For instance, the technology has been used to coat ground magnesium powder with 1–2% wax by weight in order to more than double its shelf life. When tested for firing characteristics, this coated magnesium performed as well as uncoated powder.

DoD Need

Improved ordnance manufacturing processes

Army: 3.3.c

Technology Benefits and Advantages

- Effective mixing for nano-scale materials without the use of a solvent
- Easy removal of mixing media, particularly where desired products are not magnetic
- Readily scaled up for large-scale production usage
- Relatively inexpensive equipment requirements
- Wide application and cross use of equipment
- Reduced worker and environmental risk due to the elimination of organic solvents and associated fire hazards

Technology Limitations

- Risk with impact-sensitive materials is still being evaluated as the technology is under development.
- As with the usage of all dry powder processes, process equipment must be grounded meticulously to avoid dust explosion.

NDCEE FY03 Accomplishments

- Compared effectiveness of mixing with MAIM to other mixing techniques
- Verified that MAIM provides uniform mixing of aggregated materials, usually without degradation of the aggregates
- Developed a suite of microscopically based characterization techniques to determine effectiveness of mixing

Economic Analysis

Because the technology is still in development, a detailed economic analysis has not been performed. However, cost estimates that are related to process scale-up using the MAIM technology, in contrast to original solvent-based scale-up (with explosion-proof electrical equipment), results in substantial savings in equipment cost. Additional operating savings are expected due to the elimination of solvent usage and associated waste management and air emission treatment issues.

Suggested Implementation Applications

MAIM is being developed to support several DoD programs including Green Gun Barrel, Green Bullet and Ammunition, and Advanced Materials. A key application area would be mixing components of complex propellant, explosive, and pyrotechnics materials, particularly where smaller-sized ingredients can be shown to benefit performance. It can also impact existing formulations where fine particles in size range 0.5–10 microns are already used, for example, in a number of delay compositions.

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Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R2-3)

Micro-Electromechanical System for Detection of Corrosion Underneath Coatings

The NDCEE is identifying, investigating, and developing micro-electromechanical system (MEMS) technologies that can be used to measure, control, and prevent corrosion. Specifically, the NDCEE is designing, developing, and testing prototype corrosion sensors for U.S. Army tactical vehicles. The purpose of these sensors is to detect the onset of corrosion underneath coatings to permit condition-based maintenance to reduce life-cycle costs.

Technology Description

Microdomain systems include those that are 10 centimeters in size and smaller. MEMS devices fall into this category and are typically thought of as having micro- or micron-scale features. The term "MEMS" originally applied to silicon micromachined miniaturized electromechanical systems, but now refers to any subminiaturized system including chemical sensors and nonsilicon-based structures.

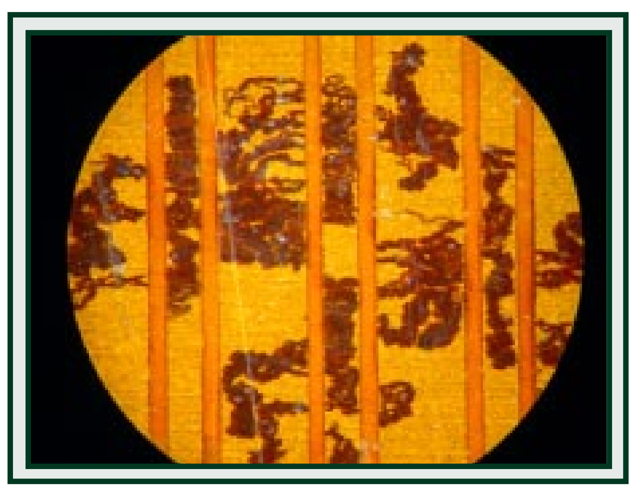
The NDCEE is currently developing and testing a linear polarization resistance (LPR) corrosion sensor. The sensor consists of several sensing elements, a data logging device, and LabView™ software. Each sensing element consists of a set of interdigitized electrodes that are made from the same material as the substrate to be monitored and attached to a polymer sheet. The sensing element is approximately 1 x 2 centimeters in area and 50 microns thick. The current testing and development effort is focused upon developing reliability data and application techniques for future field testing.

Technology Benefits and Advantages

- Detects the onset of corrosion in vehicles
- Improves mission readiness through reduced risk of vehicle and equipment failure
- Reduces operator and maintenance costs that are associated with corrosion of ground vehicles
- Reduces development time and cost with use of a more mature sensor technology
- Reduces the time and effort that are required to develop the sensor to where it can be field-tested with the use of COTS software and equipment parts

DoD Need

Corrosion detection and prevention in tactical vehicles and equipment



MEMS sensors are designed to monitor corrosion of mild steel, typically used in military vehicle construction.

Technology Limitations

- Still in testing and development stage
- High sensor cost in prototype quantities ($100 per sensing element)

NDCEE FY03 Accomplishments

- Tested and evaluated the corrosion-sensing MEMS device that was constructed by the NDCEE
- Prepared and submitted a Final Report documenting the evaluation findings. The LPR sensors were tested under a chemical agent resistant coating and were able to detect the presence of moisture from permeation through the coating and from coating damage. The sensors gave LPR output from which instantaneous corrosion rates can be calculated, but validation of this output through additional testing is required before quantitative results can be reported.

Economic Analysis

Corrosion has a significant impact on the readiness, reliability, and cost of ownership of weapon systems, support equipment, and infrastructure. The estimated cost of corrosion to the DoD is $400 million per week, of which approximately one third is considered avoidable through the use of new and improved corrosion prevention or control techniques. Specific reductions in life-cycle costs that are associated with the use of corrosion-detection sensors are expected to be identified during field testing.

Implementation of condition-based maintenance requires the accurate assessment of material conditions to make proper maintenance decisions and realize cost savings. Future assessment of these technologies with respect to providing reliable under-paint corrosion rate and cumulative corrosion loss data is required to meet this goal.

Suggested Implementation Applications

The corrosion sensor can be used on ground vehicles, aircraft, watercraft, weapon systems equipment, and munitions. These sensors would be placed in high-moisture, hard-to-reach areas. Initial field testing and application is planned for ground vehicles.

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Applicable NDCEE Tasks

Corrosion Measurement and Control Program (Tasks N.255 and N.304)

Microfiltration Systems

The NDCEE has extensive expertise with filtration systems. Several systems are featured in the NDCEE Demonstration Facility, where they are used by DoD and industrial facilities for demonstration and validation purposes. For instance, the NDCEE helped Red River Army Depot to validate a microfiltration system as an aid to extending the solution life of its zinc-phosphate pretreatment baths and thereby increasing production efficiency. Most recently, the NDCEE installed three microfiltration systems at Tobyhanna Army Depot to be used in conjunction with its plating lines. The NDCEE also worked with Oklahoma City Air Logistics Center and Corpus Christi Army Depot in determining that the bath life of alkaline rust removers that are currently in use could be greatly extended by using a microfiltration system.

DoD Need

Improved treatment of effluent discharges

Service Need Numbers

Air Force: 600-643, 1200-1276

Army: 2.2.a, 2.2.e, 2.2.f

Navy: 2.II.01.q, 3.I.03.b, 3.I.11.b, 3.I.11.j, 3.I.13.a, 3.III.06.d

Technology Description

Microfiltration provides a 1.0–0.1-micron absolute barrier that removes emulsified oils, greases, and particulate matter from filtered liquids, primarily alkaline cleaners. The typical configuration (known as cross-flow filtration) is a low-pressure (e.g., 5–40 pounds per square inch @ gauge), energy-efficient flow of liquid across the inner surface of a microfilter tube. Systems are available in different materials of construction and membrane pore diameters to accommodate unique bath characteristics (e.g., chemistry, volume, types of contaminants, and throughput).

These particular microfiltration modules are fabricated from graphite material that is formed into a tubular configuration. Wastes that are pumped into these tubes form a dynamic membrane that produces a high-quality filtration medium and removes all particles larger than the pore size. Turbulence helps to maintain membrane cleanliness, although periodic maintenance is recommended.

Applications include removal of heavy metal particles from semiconductor and components manufacturing as well as oil and grease removal from industrial laundry effluent and plating line cleaning baths.

Microfiltration system housed at the NDCEE Demonstration Facility.

Technology Benefits and Advantages

- Removes suspended particulate matter, oils, and greases from effluent discharges and reduces the frequency of bath changes
- Maintains a more stable bath consistency, thereby reducing process variation
- Reduces material and operating costs because chemical usage is reduced, secondary cleaning requirements (i.e., parts rework) are decreased, and less sludge/hazardous waste is generated/disposed
- Reduces worker health and safety risks by reducing chemical usage/handling
- Reduces waste solution discharges to industrial waste treatment plants
- May result in affordable payback period with system costs ranging $10,000–$35,000
- Helps facilities to meet pretreatment standards for discharges of wastewater to treatment plants or effluent limits of NPDES permits

Technology Limitations

- Filtration membrane can become clogged with oil/

grease if an oil coalescer is not used as part of the microfiltration process.

- Periodic cleaning of the membrane is required to optimize efficiency, adding to the operational cost of implementation.
- Proper sizing of the membrane is required to minimize loss of cleaner and/or surfactant.

NDCEE FY03 Accomplishments

- Performing optimization trials with the bench-scale microfiltration unit that is housed at the NDCEE Demonstration Facility as a follow-on to the FY01/FY02 alkaline rust remover task (Task 000-01 Subtask 5). This study is investigating various types of membrane materials to determine the most effective membrane for removing solids from alkaline rust removers that are currently in use at OC-ALC and CCAD.
- Produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with testing and evaluating four brands of microfiltration systems on behalf of TYAD. Based on performance results, a full-scale demonstration then was conducted on two of the systems using cleaners that will be utilized by TYAD. As part of its technology evaluation, the NDCEE also conducted a cost-benefit analysis using the ECAM℠ tool and projected parameters for TYAD cleaning/plating lines. The NDCEE installed three Aqualogic MM-325 microfiltration systems at TYAD due to positive performance and optimum economic factors. The microfiltration systems are helping to reduce the volume and frequency of cleaning bath solution disposal and associated disposal costs. They also are improving the consistency (and therefore quality) of the component cleaning process, resulting in less rework.

Economic Analysis

The results indicated that installing microfiltration equipment would yield an acceptable payback period on three of the original seven plating lines that are initially under consideration at TYAD. Microfiltration systems from two manufacturers were considered: the MM-325 from Aqualogic, Inc. and the Silverback 150 from U.S. Filter Corporation. The MM-325 yielded a simple payback of 3.5 years, and the Silverback 150 yielded a simple payback of 4 years. While capital costs for the MM-325 were slightly higher than for the Silverback 150, $90,453 compared to $89,476, the MM-325 annual operating costs were lower: $58,403 vs. $61,566. Annual operating costs for the current process (no filtration) are $84,088. The MM-325 also offered a greater process throughput rate and better cleaning efficiency than the Silverback 150. The baseline process at TYAD does not currently recycle cleaning bath solutions.

Suggested Implementation Applications

This technology is applicable for any site with wastewater issues, particularly those that are connected with industrial operations such as electroplating lines. For instance, TYAD cleans and plates a wide variety of parts in all configurations and sizes from many DoD weapon systems. The parts are mostly from ground support equipment such as trucks and trailers. Other parts that are processed are from surveillance equipment, satellites, radios, and other communication equipment. Two specific systems supported by TYAD are Guardrail™ and FireFinder™. Guardrail™ is a Corps Level Airborne Signal Intelligence collection/location system; FireFinder™ is a mobile radar system.

Points of Contact

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Applicable NDCEE Tasks

Alternative Cleaning Solutions Recycle/Recovery (Task N.000-01, Subtask 5)

Pollution Prevention Initiative (Task N.227)

Mobile Wood Recovery Unit

The NDCEE is helping the DoD and its installations to identify optimal methods for the recovery of reusable and recyclable building materials and components that are generated through construction, deconstruction, and demolition activities. As part of this effort, the NDCEE identified the wood recovery unit as potentially suitable for use in the deconstruction of wood buildings once the unit becomes commercially available.

Technology Description

The wood recovery system is a self-contained unit that is designed to produce value-added wood products from painted wood siding, especially siding coated with lead-based paint (LBP). The unit is configured for easy site-to-site mobility, eliminating the high cost of transporting hazardous materials to fixed facilities.

Odd-shaped, random-sized, dirty, coated wood materials are fed through the input opening of the unit and retrieved from the opposite side as clean, uniform stock material. Test results indicate that the wood product is nonhazardous, and preliminary research shows that markets exist for the end product. Designed to process 100 linear feet of material per minute, the unit could service multiple projects within a 40-hour workweek. For example, the system processed wood siding that was recovered from two two-story barracks in less than two days at Fort Ord.

The key internal components of the portable wood recovery system are: 1) an Auburn Machinery, Inc.'s Yield Pro to machine the wood surface and 2) a high-efficiency particulate air (HEPA) filter dust collection system. The onboard support systems include a sealed sawdust storage chamber, sawdust discharge and bagging station, air compressor, 80kW generator, and fire suppressor. These components are contained in a 28-foot gooseneck trailer, which can be pulled by a standard truck.

Technology Benefits and Advantages

- Converts hazardous materials (e.g., LBP-coated wood) into nonhazardous, uniform stock that is ready for value-added processing
- Is a self-contained, portable unit
- Can accept nail-embedded wood with special tooling
- Helps facilities to meet a DoD Pollution Prevention Measures of Merit mandate for 40% (wt.) landfill diversion by 2005

DoD Need

Nonhazardous solid waste reduction

Service Need Number

Army: 3.5.c

Technology Limitations

- This prototype system is still undergoing testing and has not been made commercially available.
- Facilities may need appropriate regulatory permits.
- The unit is not designed to process wood pieces larger than 3 inches thick and 12 inches wide.
- The unit typically cannot accept wood embedded with metals. These materials must be presorted and segregated from the inventory stock.

The mobile wood recovery unit removes lead-based paint from wood siding, producing clean, uniform stock material.

- Depending on the coating material, the process may produce hazardous by-products such as LBP-contaminated sawdust (some of which becomes airborne). Although this waste component will require further treatment or disposal, its volume is substantially less than that of the original LBP-coated wood, resulting in significant transportation cost savings and Subtitle C landfill tipping fee avoidances.
- Employees potentially could be exposed to airborne hazardous materials.

NDCEE FY03 Accomplishments
The NDCEE produced a Final Report that documented its efforts that are associated with identifying and evaluating concepts, methods, and technologies for rapidly reducing the overall volume of nonhazardous solid waste materials that are generated by the DoD. Included in the report is a discussion on deconstruction techniques and technologies, including an engineering evaluation of the wood recovery unit. The NDCEE witnessed a three-day demonstration of the prototype mobile wood recovery system at Fort Ord. Based on demonstration results, the system proved to be environmentally friendly. However, additional research and modifications are necessary to tailor this technology for military and commercial use.

Economic Analysis
Although the wood recovery system is currently a prototype unit, the vendor estimates a purchase price of approximately $200,000. Operating costs are presently unknown; however, during normal operation, the vendor claims that up to five laborers are required: one to sort material, one to denail the wood/feed system, one to operate Auburn Machinery, Inc.'s Yield Pro, and two on the back-end to collect the outfeed material and stack alike wood products. Other factors that will need to be considered include quality of the wood siding (e.g., old growth, number of knots, etc.), distance to hazardous Subtitle C landfills and tipping fees, employees' exposure to airborne hazardous materials, and markets for the end products.

Suggested Implementation Applications
Although it is still in development, the wood recovery unit should be ideally suited for those facilities that are deconstructing wood buildings, especially those containing LBP-coated materials.

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Applicable NDCEE Task
Nonhazardous Solid Waste (Task N.303)

Municipal Solid Waste Conversion System

The NDCEE is helping the DoD and its installations to lower the costs of solid waste management and achieve a DoD Pollution Prevention Measures of Merit goal. The goal is to divert 40% (by weight) of solid waste from landfills or incineration by FY05. The NDCEE has identified and evaluated concepts, methods, and technologies for rapidly reducing the overall volume of nonhazardous solid waste materials that are generated by the DoD, lowering disposal costs, and developing useful, recyclable products from the diverted materials. As part of this effort, the NDCEE validated demonstration findings on a prototype Municipal Solid Waste (MSW) Conversion System. The findings indicated that the system could divert upwards of 90% of MSW from landfills and convert the waste into usable cellulose end products.

Technology Description

The MSW Conversion System converts typical household garbage, such as bottles, cans, organic wastes, trash bags and plastic milk jugs, into a sanitary cellulose end-product by shredding, grinding, and "cooking" the refuse in a hydrolyzer using high-pressure steam. The output cellulose pulp may be extruded into composite lumber planks for construction or, after two stages of separation, emerge as a "fluff" material that has potential reuse applications as a soil amendment. The proprietary process, developed by Bouldin & Lawson (B&L) Corporation, was demonstrated at the Fort Benning Materials Recovery Facility (MRF) in June 2002. The three-week NDCEE demonstration used raw municipal refuse from Fort Benning's Military Family Housing (MFH).

Using a low-speed, high-torque shredder, the system reduces the raw municipal refuse into approximately 1–2-inch square pieces. Batteries, carpet, and any other unusual items that might cause equipment or personnel harm are manually removed from the input stream. The shard pieces are delivered to a conveyor system that utilizes magnetic rollers to separate out the ferrous metals. The balance of the waste is then further reduced in a smaller shredder, ground, and conveyed into a hydrolyzer. This jacketed containment vessel uses a high-temperature steam in a proprietary process to kill bacteria and viruses while breaking down carbon bonds in the material. The resultant hydrolysis product is transferred to an expeller unit (auger) that operates as a "hard" press. The internal screw-like shaft of the auger serves as a ram to shuttle the moist cellulose along an internally tapered tunnel. Water is removed from the aggregate cellulose in a rotary dryer, further ensuring the sterility of the pulp-like product. The coarse and fine cellulose mix is separated in a star screen; the coarse is deposited in a collection bin while the small fractions are tumbled through a rotary drum to remove the fines of aluminum, glass and plastic, which are gravity-fed into a "particulates" collection bin. The separated fine cellulose material emerges as a sanitized, sand-like granular fluff that may be useful as a soil amendment because of its organic base and relatively high nitrogen content. The coarse, peat moss-like material can be extruded into plastic-like composite planks.

In addition to the solid output streams, the conversion system also releases excess water vapor from the boiler and internal chambers of the hydrolyzer. A portion of this steam is captured at the hydrolyzer-to-baler material transfer point and used to moisten the grinder infeed; however, water vapor is released and not captured from many points in the system. Humid air is also discharged from the dryer.

DoD Need

Nonhazardous solid waste reduction

Service Need Number

Army: 3.5.c

This prototype MSW Conversion System was successfully demonstrated at Fort Benning.

Technology Benefits and Advantages

- Converts MSW into cellulose end-products, such as plastic-like lumber or material, that have potential use as a soil amendment
- Processes over 90% of the unsegregated, base-generated municipal solid waste stream input
- Helps facilities to meet a DoD Pollution Prevention Measures of Merit mandate for 40% (wt.) landfill diversion by 2005

Technology Limitations

- This system is still undergoing testing and has not been made commercially available. At this stage, without appropriate coordination and design intervention, a variety of suboptimum designs of this system could emerge on various military installations as a result of each agency's rushing to meet the Measures of Merit reduction requirement and not coordinating efforts.
- Facilities will require appropriate regulatory permits.
- Output will be dependent on the composition of the MSW input stream. For example, Fort Benning's MFH MSW waste stream has a relatively low plastic content due to the efficiency of the base's recycling program. The low plastic content may result in poor structural properties of the extruded composite planks.

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report that documented its efforts associated with identifying and evaluating concepts, methods, and technologies for rapidly reducing the overall volume of nonhazardous solid waste materials that are generated by DoD. Included in the report is a discussion on NDCEE's three-week demonstration at the Fort Benning MRF in FY02 in which 36.2 tons of raw material refuse was processed, leaving 3.3 tons segregated. At the conclusion of the demonstration, the B&L system had produced 10 tons of cellulose fluff for a future soil application study and 37 extruded 2-inch x 4-inch x 8-foot planks for subsequent CERL structural tests. The resultant cellulose end-product realized an approximate 50% reduction in volume and 20% reduction in mass.

Economic Analysis

An estimated total investment of $835,000 is necessary to acquire equipment that is comparable to that demonstrated at Fort Benning. For each hour of operation, the MSW conversion system processed an average of 1.1 tons of MSW at a fully burdened, estimated operating cost of $77 per ton. The cellulose end-products demonstrated a reduction of the total raw waste input of approximately 50% by volume and 20% by mass.

The MSW Conversion System produces cellulose pulp that may be extruded into composite plastic-like planks (similar to the planks in white above).

In its current state of process development, the MSW conversion system is able to process 93% of the total, unsegregated, base-generated MSW stream. As determined from the NDCEE waste stream characterization study, MSW represents approximately 60% of the total solid waste streams that are generated by military installations. By processing 93% of the MSW that is generated, as much as 56% of the total military-generated solid waste stream could be diverted from landfills, dependent upon a final analysis of the end-products. To put these percentages into context, if the technology is successfully implemented, 1.9 million tons of MSW per year could be diverted from landfills or incineration. This tonnage amount is based on the approximately 2.13 million tons of MSW that was generated in FY99. Associated FY99 disposal costs were more than $100 million. Costs

are expected to increase dramatically over the next several years with the added pressures of mandated military environmental stewardship and remediation liability for older landfills that have started to leak.

Suggested Implementation Applications

This technology will benefit any facility or rapid deployment site that processes MSW. For instance, the U.S. Air Force is seeking a similar system that could "fit into a C-130" for rapid desert deployment.

Points of Contact

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Applicable NDCEE Task

Nonhazardous Solid Waste (Task N.303)

NitroCision™ CryoJet System

The NDCEE has significant technical expertise with coatings removal systems. As a result, the NDCEE was tasked to identify potential alternatives to chemical or mechanical coatings removal processes for use on delicate substrates, many of which are also dimensionally critical parts.

Technology Description

The patented NitroCision™ CryoJet System uses a high-velocity gaseous liquid nitrogen stream for cutting, cleaning, abrading, and coatings removal applications. Coatings removal is achieved through a combination of temperature and liquid nitrogen pressure. The temperature and pressure of the liquid nitrogen stream can be adjusted to control the aggressiveness of the coatings removal. The only discharge from this system is harmless gaseous nitrogen and the removed coating material.

Developed by NitroCision, LLC, a subsidiary of TruTech, LLC, this skid-mounted system consists of a liquid nitrogen supply tank, a pre-pump to increase the stream pressure to approximately 15,000 pounds per square inch (psi), and additional intensifiers to increase the stream pressure up to approximately 60,000 psi. The prepump and the intensifiers require a 480-volt, 200-amp, 3-phase power source. The nitrogen stream produced by this equipment can be controlled using a handheld wand (for use with lower pressures) or an automated control unit. Several nozzle configurations are available to adjust the approximate width of the spray path from 2–14 millimeters. Multiple spray nozzles can increase the width of the spray path to approximately 64 millimeters.

The CryoJet process has demonstrated coatings removal rates up to 10 square feet per minute. The unit consumes approximately 2–3 gallons of liquid nitrogen per minute. The unit can be operated at pressure ranges from 12,000–60,000 psi and temperature ranges from -391 to 212°F (-235 to 100°C). Adjustments to temperature and pressure control the aggressiveness of coatings removal. The effective range of the nitrogen stream is approximately 12 inches.

DoD Need

Environmentally preferred coatings removal technique

Service Need Numbers

Air Force: 100-202, 213, 221, 304, 309, 322, 327; 200-332; 900-2095; 1700-1754

Army: 2.1.h, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

Technology Benefits and Advantages

- Eliminates hazardous airborne particulate from blasting operations, decreases solid waste, and eliminates the use of chemical strippers
- Reduces labor and operating costs as a result of decreased preremoval preparation and post-removal cleanup
- Improves safety and health working conditions due to the elimination of airborne emissions of heavy metals and other contaminants when used with vacuum recovery
- Helps facilities to comply with Executive Order 13148, which requires the DoD to decrease the amount of waste that is generated at federal facilities, as well as environmental regulations regarding airborne particulate emissions

Technology Limitations

- Is still under development
- Produces a gaseous nitrogen stream, which can be collected with the removed coatings using a recovery system
- Poses safety risks that are associated with the handling of the low-temperature liquid nitrogen and possible oxygen depletion when the system is used in confined areas
- Has line-of-sight limitations due to linear orientation of the nitrogen stream
- Requires operational and maintenance training

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with evaluating the feasibility of using the NitroCision™ CryoJet System for coatings removal. These activities included:

- Producing an Alternatives Report that identified the needs and requirements for alternative coatings removal technologies from delicate substrates. The CryoJet system was recommended for evaluation of special hull treatment and passive countermeasure system (pcms) tiles as well as radomes.
- Conducting a demonstration of the CryoJet capabilities at the vendor facility in Idaho Falls, Idaho. Weapon system components that were demonstrated included a HMMWV hood, Navy and Air Force radomes, and PCMS tiles.
- Producing a Demonstration Report that summarized key results that were used to assess alternative coatings removal technologies and compared their performance to the baseline removal methods.

Economic Analysis

The capital and operating costs of the CryoJet technology are currently unknown because the technology is still under development. However, some maintenance cost issues have been identified. Maintenance will include routine maintenance of the 100 horsepower prepump and other system components. The intensifiers will require seal replacement after every 400 hours of operation. The seal kit cost is approximately $1,200. The system also will require standard cleaning and inspection. Depending on the system configuration, additional maintenance of the recovery system and automation components may be required.

Suggested Implementation Applications

Additional system development and evaluation is needed before the CryoJet system is ready for implementation. Potential uses include coatings removal from Navy and Air Force radomes, HMMWV hoods, and antenna fairings.

Points of Contact

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Applicable NDCEE Task

Pollution Prevention Initiative (Task N.227, Mod 1)

Noncyanide Finishing Processes

The NDCEE was tasked to find alternatives to cyanide-bearing solutions that are used in plating operations, metal stripping, and other finishing processes at Corpus Christi Army Depot and similar DoD facilities. As part of its tasking, the NDCEE identified and demonstrated candidate replacement technologies. Demonstration results showed that while the noncyanide processes that were tested met some of the stakeholders' criteria, the test panels that were plated with these processes exhibited quality and adhesion problems and lacked the beneficial economic value to be considered as a suitable solution for CCAD based on workload requirements and the fact that other cyanide processes would continue to be used.

Technology Description

Noncyanide finishing processes are designed to replace those containing cyanide, which is stringently regulated at federal, state, and local levels because of its toxicity to humans. Less than 0.2 grams of cyanide can be a lethal dose for a 185-pound individual; therefore, it poses a severe hazard to those working with and around cyanide-bearing processes.

CCAD electroplating and stripping baths are sources of cyanide-containing waste. The cyanide-based electroplating baths include copper, copper strike, silver plating, silver strike, and cadmium. Cyanide-based stripping baths contain silver strip and silver solder strip (braze remover) solutions. Cyanide wastes are generated when parts with residual solution are rinsed after immersion in a cyanide-based bath or when spent baths are discarded. Bath solutions are rarely dumped and typically last several years. CCAD treats cyanide-bearing wastewater using an alkaline chlorination process. Cyanide-containing waste streams are carefully segregated from other waste streams to prevent contamination with acid, which would cause the release of toxic hydrogen cyanide gas.

On behalf of CCAD, the NDCEE identified four potential alternative processes: cadmium plating, copper plating, silver plating, and silver stripping. Due to cadmium's inclusion on the EPA's list of 17 high-priority chemicals targeted for reduction and stricter regulation, this alternative was eliminated from consideration. The remaining three processes would be drop-in replacements, with some minor modification, for the cyanide processes.

DoD Need

Alternative noncyanide finishing method

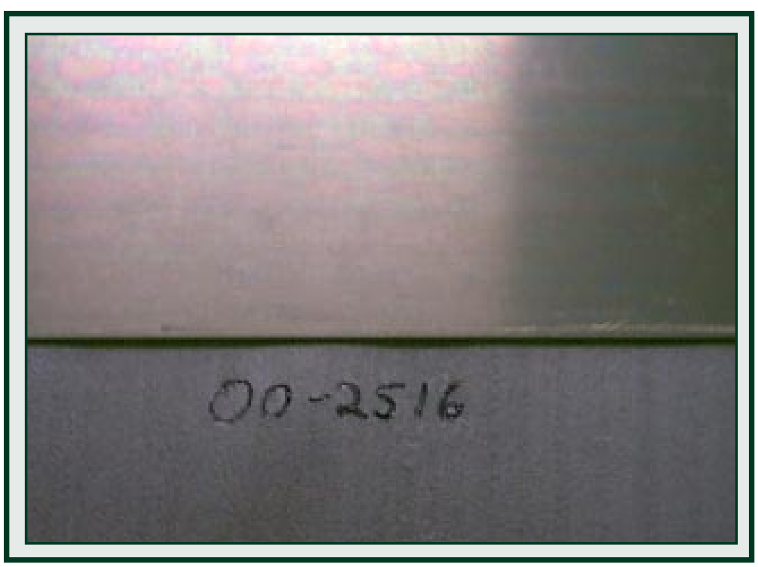
Service Need Numbers

Army: 3.1.c

Navy: 2.I.01.g, 3.I.03.e, 3.I.04.h

Technology Benefits and Advantages

- Reduces or eliminates the use of cyanide, leading to reductions in EHS risks
- Eliminates the need for a separate waste treatment process in an industrial wastewater treatment plant
- Reduces the disposal of hazardous cyanide-containing waste



Panel plated with Zinex Silvergleam noncyanide silver plating

Technology Limitations

- Results in higher capital and operating costs than cyanide processes
- May exhibit performance problems
- May require more user intervention and training than current processes

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in

connection with identifying and evaluating alternatives to cyanide-bearing solutions that are used in plating operations, metal stripping, and other finishing processes applications. Activities included:

- Identifying 11 candidate replacement processes and performing an engineering assessment of the technical probability of success for each alternative. These processes were down-selected to four processes that were based on CCAD operational requirements. The requirements were identified through a site survey at CCAD.
- Conducting performance tests on the three plating processes and one silver stripping process using a closed-loop electroplating line in the NDCEE Demonstration Facility. Demonstrations were also performed by the vendors in a laboratory scenario. Demonstration testing was conducted in accordance with the Demonstration Plan produced by the NDCEE. The substrates that were evaluated included 304 stainless steel, 7075 aluminum alloy, 2024 aluminum alloy, 4130 steel alloy, and Inconel® 718 and 4340 steel for hydrogen embrittlement testing. Test results were documented in a Demonstration Report. The analysis of the technical performance and cost of the alternatives versus the baseline processes was included in the Justification Report. The noncyanide process demonstration results indicated that the noncyanide copper and silver plating alternatives did not perform as well in the NDCEE Demonstration Facility as at the vendor facilities, indicating that the processes could require more user intervention and training than current processes. The noncyanide silver stripping performed successfully in stripping noncyanide silver plating at CCAD.

Economic Analysis
The NDCEE, with assistance from CCAD, identified several potential benefits and cost savings, but they were considered to be minimal. Additionally, implementation of the noncyanide alternatives would increase capital and operating costs. Because of the limited benefits that were offered by the noncyanide alternatives, the NDCEE did not perform extensive data collection to quantify annual life-cycle costs. Therefore, indicators such as IRR, NPV, or discounted payback period were not calculated.

Suggested Implementation Applications
Noncyanide finishing processes may potentially replace cyanide-bearing solutions that are used in plating operations, metal stripping, and other finishing processes. Maintenance shops use these processes on a variety of aircraft, vehicles, and weapon system components. For instance, CCAD provides aviation maintenance for helicopter weapon systems including UH-60, AH-64, CH-47, UH-1, OH-58, MH-60, SH-60, and AH-1. However, the NDCEE found that the noncyanide finishing processes exhibited quality and adhesion problems when demonstrated in a production environment and lacked the beneficial economic value to be considered as a suitable solution for CCAD. This finding could be applicable for other facilities.

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Applicable NDCEE Task
Pollution Prevention Initiative (Task N.227)

Non-Line-Of-Sight Alternatives to Hard Chromium Plating

Under a U.S. Air Force-sponsored effort, the NDCEE was tasked to identify, evaluate, and validate environmentally acceptable alternatives to hexavalent chromium electroplating for NLOS applications. Generally, NLOS applications refer to complex-shaped components that possess internal diameters, blind holes, and other complex features. Subsequent site studies at three Air Logistics Centers revealed that 20%–40% of the chromium-plated parts require NLOS processes for the refurbishment of coatings, which cannot be treated with HVOF technologies because of their line-of-sight limitation. This NDCEE effort was later expanded under a second task to include U.S. Army and Navy applications and additional NLOS alternatives.

DoD Need

Environmentally preferred surface protection and corrosion control

Service Need Numbers

Air Force: 100-101, 117, 186, 210, 251, 258, 285, 291; 200-312, 337, 339; 800-852; 900-909, 2111; 1600-1603

Army: 3.1.c

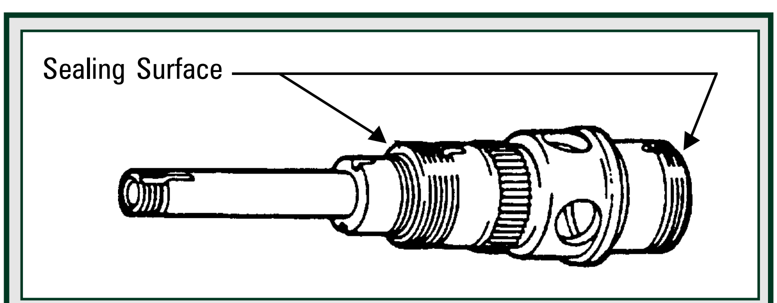
Navy: 2.I.01.g, 3.I.03.e, 3.I.04.h

Technology Description

The NDCEE has investigated the following four NLOS technology categories. For any of the evaluated processes to be considered as a viable alternative to hard chromium, it had to meet or exceed specific performance characteristics, including guidelines outlined in the Federal Specification Chromium Plating (Electrodeposited) QQ-C-320B for Class II Engineering Plating, as well as pass additional requirements established by the NLOS Team.

Electrolytic Plating: Conventional plating equipment is used to deposit electrolytic coatings, and the process sequence is similar to hard chromium plating. The NDCEE investigated electrolytic nickel-tungsten (65% by weight Ni, 35% by weight W) and a nanoparticle electrodeposition process (Nanoplate). The Nanoplate process electrolytically deposits coatings that consist of nanocrystalline-sized nickel particles and the respective alloying element (e.g., molybdenum and cobalt). The coating evaluated by the NDCEE was the nickel-molybdenum alloy (99.5% Ni, 0.5% Mo).

Electroless Nickel (EN) Plating: This process is also known as chemical or autocatalytic nickel plating. In contrast to the electroplating (galvanic) technique, this chemical nickel plating process works without an external current source. The plating operation is based upon the catalytic reduction of nickel ions on the surface being plated. EN coatings are classified into three main types: nickel-phosphorus (ENP), nickel-boron, and poly alloys. The most popular EN, nickel-phosphorus, is generally used for engineering applications. It is deposited by the catalytic reduction of nickel ions with sodium hypophosphite in acid baths. Variations on the ENP process include ENP with boro-nitride particles and ENP silicon carbide. Nickel-boron is primarily used in industrial wear applications for its as-plated hardness, which is higher than that of nickel-phosphorus. Poly alloys are a combination of nickel, boron, or phosphorus and other metals such as cobalt, iron, tungsten, rhenium, or molybdenum. Composite deposits such as EN-polytetrafluoroethylene and EN-diamond have been developed for special applications.



This aeronator valve, which is a component treated at Oklahoma City ALC, is an example of an NLOS application.

Iron Plating: Electrolytic hard iron has been produced and utilized for a number of years. Its use has been limited to applications in which wear resulting from lack of lubrication was not a consideration. The process is extremely complicated when used to achieve both desirable and functional metallurgical properties. However, the majority of iron plating solutions are stable and easy to

operate. Most electrolytic iron is highly stressed and brittle and it, as well as the basis metal, is highly subject to hydrogen embrittlement. Iron's primary uses include, but are not limited to, protection of soft or perishable metals and alloys, reinforcing fragile metal forms, and providing a magnetic surface on nonmagnetic materials. A number of iron plating bath solutions are available and commonly include chloride, sulfate, fluorborate, sulfamate, and other proprietary solutions. The iron plating process that was investigated by the NDCEE achieves an electroplate with a microstructure that enables it to resist wear and coining. This reclamation process has been proven over the years to be able to restore worn, improperly machined, or salvaged service parts.

Trivalent Chromium Plating: This process eliminates the use of chromic acid, thereby reducing health risks to operators. Trivalent chromium forms insoluble mineral precipitates in groundwater, which eliminates the chemical reduction step in wastewater treatment. As a result, the treatment process is simplified and overall treatment costs are reduced. The trivalent chromium plating process investigated under this effort is deposited electrolytically, but no special fixturing or racking is required. Carbon anodes are recommended for this process, as is an ion exchange unit for the removal of contaminants from the plating bath.

Technology Benefits and Advantages

- Improves safety and worker health conditions due to the reduction or elimination of hexavalent chromium
- Reduces the operational costs and labor requirements as a result of eliminating hazardous materials and the associated compliance procedures/processes
- Reduces waste generation
- Produces coatings that are in accordance with the requirements listed in Federal Specification QQ-C-320B and are easily removable
- Extends wear life of original components and reduces maintenance costs

Technology Limitations

- The trivalent chromium process that was investigated requires a licensing agreement.
- The iron plating process that was investigated is extremely complicated when used to achieve both desirable and functional metallurgical properties.
- The trivalent chromium and the electrolytic plating processes require additional technology development prior to implementation.

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with evaluating and validating environmentally acceptable alternatives to hexavalent chromium electroplating for NLOS applications. Activities included:

- Performing site surveys at Anniston Army Depot, Naval Aviation Depot-Jacksonville, Naval Aviation Depot-Cherry Point, and Naval Aviation Depot-North Island to identify NLOS chromium-plated parts, the coating requirements for those parts, and relevant processing methods for each part.
- Identifing and assessing three NLOS technologies to apply various coatings for DoD NLOS applications: trivalent chromium plating, electroless nickel plating, and iron plating.

- Preparing and submitting a Requirements Report, Alternatives Report, Demonstration Plan, Demonstration Report, Justification Report, and Implementation Report. These reports document the Army and Navy requirements, the selected alternatives, the demonstration activities, the economic analysis for the best performing alternative, and the plan for implementing that alternative.

Economic Analysis

Using the ECAM℠ tool, the NDCEE performed an economic analysis on two NLOS alternatives: EN and iron plating processes. An ECAM℠ was not performed for the trivalent chromium or electrolytic plating processes because demonstration test results revealed that further technology development was required for these processes.

The ECAM℠ for the EN plating process showed that this technology is not cost-effective. The NDCEE recommended that no further action be taken with this technology until it can be further refined and shown to provide a potential for cost savings.

For the iron plating process, two ECAM℠ scenarios were completed. The ECAM℠ revealed that the annual costs for Scenario 1 (EHC processes are successfully converted to the HVOF process for line-of-sight components and the iron plating process for NLOS components) were approximately one third less than the baseline costs. The annual cost savings were $10,829.29, and the simple payback period was less than 2 years. The NPVs after 5, 10, and 15 years were in excess of $30,000, $70,000, and $100,000, respectively. Also, the IRR values ranged from 49–56%. The ECAM℠ results for Scenario 2 (all hexavalent chromium processes were not converted) showed that if hexavalent chromium cannot be completely replaced, the scenario for the use of iron plating is not cost efficient. The NPVs all show negative values that indicate a loss, and values for IRR and payback period indicate that no return is expected on this investment.

Suggested Implementation Sites

This technology may benefit DoD maintenance facilities that use hexavalent chromium compounds for the repair of worn coatings. Approximately 20%–40% of all hard chromium plating activities at Air Logistics Centers are completed for NLOS applications.

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Applicable NDCEE Task

Pollution Prevention Initiative (Task N.227, Mod 1)

Photochemical Depainting System

The NDCEE has evaluated the feasibility of using the prototype Photochemical Depainting System to remove coatings from radar domes (radomes) or radome pieces. Development of this system has significant implications to SIMA Mayport Paint Shop, Tinker AFB, and other depots where radomes are depainted.

Technology Description

The Photochemical Depainting System removes coatings from parts without the aid of chemicals, and therefore, without emitting VOCs or HAPs. The system replaces other coating removal processes such as hand sanding, the use of abrasive media, VOC- and HAP-containing strippers, and acid-based strippers.

Developed by Green Oaks Research Laboratory, Inc., the system consists of intermittent exposure of a sample to a stripping media and ultraviolet (UV) light. A stripping media of polyethylene oxide (PEO) and hydrogen peroxide (H_2O_2) is sprayed onto the coated substrate, causing the coating to eventually detach. Spray times and UV exposure times vary, but the total average exposure times have ranged 2–8 hours.

During Phase II of a Small Business Innovative Research Program, funded by Naval Air Warfare Center Aircraft Division, the process was transitioned from laboratory scale to an automated field unit. The field unit can handle up to 5-foot x 5-foot low-profile components.

The initial proof-of-concept involved altering the process variables, including the UV photon flux, H_2O_2 levels, infrared heating, and PEO concentrations. The tests were extended to a wide range of paints and primers including epoxies, polyurethanes, acrylics, and lacquers. Various substrates of wood, stainless steel, aluminum, and composites were tested. Initial results showed successful removal of the paint with no visible impact or damage to the substrate.

DoD Need

Environmentally compliant paint removal method

Air Force: 1232, 225, 580, 814, 988, 1468, 120, 311

Army: 2.1.h, 2.3.k, 3.2.j

Navy: 2.I.01.g, 2.I.01.q, 3.I.05.a

Technology Benefits and Advantages

- Reduces or eliminates both the generation and release of hazardous waste/ materials into the environment
- Reduces worker exposure to VOCs/HAPs, reducing lost work time and health care costs
- Meets or increases the production and maintenance goals without any degradation of part quality

Technology Limitations

- Technology is in the developmental stage and has only been demonstrated on test pieces and radome pieces.
- Scale costs to accommodate large aircraft components are unknown.
- Substrate damage is unknown.

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion of NDCEE activities on evaluating and validating a Photochemical Depainting System. Activities included:

Military aircraft should benefit from the Photochemical Depainting System that is currently in development.

- Obtaining baseline information and requirements for a technology demonstration from SIMA Mayport Paint Shop and Tinker AFB. The findings were documented in a Requirements Report.
- Producing a Demonstration Plan that was used by the technology developer to conduct a demonstration using the depainting system for removing coatings from a variety of radome substrates.
- Performing an economic analysis using the ECAM^{SM} tool and baseline costs that were provided by SIMA Mayport. The analysis was conducted assuming that the photochemical depainting would be a replacement for hand sanding of radomes.
- Producing a Demonstration and Justification Report that provided the technical and economic findings of the NDCEE evaluation of the Photochemical Depainting System. U.S. Navy personnel deemed the removal of the coatings from Navy radome pieces satisfactory after inspection. The ozone monitoring results showed that the time-averaged ozone generation from the booth is insignificant from a health hazard perspective.

Economic Analysis

The ECAM^{SM} indicated a payback of 5–11 years based on the estimated capital expenditure of $100,000–$200,000. Because the depainting system is still in the development stage, this analysis is based on the estimated costs for this technology. Therefore, the NDCEE recommends that another cost-benefit analysis be conducted when more precise capital and operating costs become available.

Suggested Implementation Sites

Any DoD sustainment facility that uses manual depainting methods or chemical strippers to remove coatings from components, such as U.S. Navy and Air Force radomes and aircraft components (e.g., C5 aircraft components), would benefit from this system.

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Applicable NDCEE Task

Pollution Prevention Initiative (Task N.227)

Two views of the prototype Photochemical Depainting System

Physical Vapor Deposition Systems

The NDCEE has demonstrated and evaluated the feasibility of using physical vapor deposition (PVD) systems to deposit several coating types on a variety of substrates. The NDCEE has determined that PVD processes can be used to extend original component life, thereby resulting in a reduced frequency of hard chromium plating on a per part basis. EHC plating is used by most DoD maintenance facilities to refurbish gas turbine engines.

Technology Description

PVD processes are film deposition processes in which atoms or molecules of a material are vaporized from a solid or liquid source and transported in the form of a vapor through a vacuum or low-pressure gaseous environment, then condensed on a substrate. The NDCEE conducted demonstrations of the following four PVD technologies as alternatives to EHC.

Cathodic Arc Deposition: This process has emerged as one of the most powerful and versatile technologies that can apply a high-performance, hard coating at temperatures below 800°F. It may be used to evaporate almost any metal or alloy. Other key advantages of using cathodic arc are high deposition rates with excellent coating uniformity. Coating uniformity is attributed to the improved throwing power of the process, as compared to conventional PVD processes. The throwing power results from the high ionization of coating material. The high percentage of coating material ionization, combined with substrate biasing leads to excellent film adhesion and denser coatings than conventional PVD processes. In general, good quality films are deposited throughout a wide range of deposition conditions. Another key advantage of cathodic arc is the minimal amounts of waste generation that is incurred. Waste generally consists of pump oil, and possibly small amounts of dry, flaky coating materials.

Ion Beam Assisted Deposition (IBAD): IBAD is a coating process that aims to improve density and adhesion and control the microstructure of the coating. It incorporates both a means of PVD and simultaneous energetic ion bombardment. Unlike other PVD systems, IBAD offers a full-density coating due to the bombardment of high-energy ions and the tailoring of process parameters. The fatigue strength of components also can be improved. Like glass bead peening, the high-energy, bombarding particles create residual compressive stress on the surface of components that can improve the fatigue strength of materials. This benefit can be significant for some critical components such as aircraft landing gear. IBAD is used to deposit coatings at low temperatures, which make the process applicable for temperature-sensitive materials.

Plasma Immersion Ion Processing (PIIP): PIIP is a relatively new vacuum technology for the application of hard, wear-resistant coatings. Like conventional PVD methods, PIIP is used to deposit various coatings, but the NLOS PIIP approach allows simultaneous treatment of large components and complex shapes without requiring component manipulation. The same

DoD Need

Environmentally preferred surface protection and corrosion control

Service Need Numbers

Air Force: 200-311, 900-1952

Army: 3.1.c, 3.10.f

Navy: 3.I.03.b, 3.I.04.h

With this PVD technology, components are placed within the chamber and then coated.

equipment can be used to deposit coatings from hydrocarbon gases or organometallic compounds.

Sputtering: Sputtering is a coating and surface modification technique that occurs when an energetic particle impinges upon a material—either a solid or liquid. It can be used for a variety of applications: removing surface contaminants and barrier layers prior to film deposition, micromachining, etching, thinning, gettering, surface analysis, and thin film deposition. For thin film deposition, it provides the advantage of atomically cleaning surfaces *in situ*, thereby eliminating the need to transfer the cleaned substrates to another processing system. Sputtering can be used to produce functional coatings with a wide variety of properties such as wear-resistant surfaces, corrosion-resistant layers, diffusion barriers, electrical conductance with controlled resistance, insulating properties, reflectivity, catalytic surfaces, and good adhesion layers.

Technology Benefits and Advantages

- Can be used to either remove surface contaminates and/or apply coatings
- Reduces the use of hexavalent chromium, leading to reductions in EHS costs
- Reduces operator exposure to hexavalent chromium
- Reduces waste generation
- Improves wear life

Technology Limitations

- The IBAD system has higher equipment costs as compared to electroplating and other PVD processes. Extensive training is required for operators.
- Cathodic arc deposition and IBAD are line-of-sight processes and have surface area limitations.
- IBAD technology is in commercial infancy.
- With cathodic arc deposition, the possible occurrence of entrapment of the macroparticle inclusion in the growing film can result in nonhomogeneity in the microstructure and detrimental physical properties.

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with identifying and evaluating alternatives to chromium-bearing solutions that are used in plating operations, metal stripping, and other finishing processes applications. Activities included:

- Producing a Demonstration Plan that outlined the activities that are necessary to demonstrate each of the selected EHC alternatives and the test methods and procedures that are used to evaluate the coatings and surface modifications. The alternatives had been identified in a Potential Alternatives Report for Ion Beam and Plasma-Based Alternatives to Chrome Plating of Gas Turbine Engine Parts.
- Demonstrating "next-generation" coatings/surface alternatives for DoD propulsion applications that offer the potential for dramatic improvements in the service life of original components, leading to longer service intervals and, hence, reduced use of chromium for repair processes. Depending on the PVD technology that is being demonstrated, a diamond-like carbon (DLC) coating, chromium and tungsten carbide coating, tungsten carbide/carbide coating, chromium nitride (CrN) coating, and/or a CrN and niobium nitride super lattice coating were deposited on Inconel 718 (IN718) nickel super alloy and 4340 steel substrates—the most prevalent materials in a gas turbine engine. The demonstrations were performed at vendor facilities.
- Performing corrosion, wear, adhesion, and nanohardness tests on deposited

coatings in accordance with the NDCEE Demonstration Plan to screen alternative coatings.

- Producing a Demonstration Report that documented the results of the demonstration/validation activities to determine the effectiveness of coatings produced via PVD methods. Based on the overall test results, DLC coatings that are deposited via PIIP performed better for wear resistance on 4340 steel, but were not tested at the highest loads on IN718 because they are expected to degrade at the temperatures that are experienced in typical service applications. Therefore, the DLC coatings are recommended for 4340 steel components only. The titanium-implanted 4340 steel panels performed better than the other implants. CrN deposited via IBAD appears to be a good candidate for both 4340 steel and IN718 substrates. Based on the positive results, the NDCEE recommended that other variations of CrN, including those that are produced by sputtering and cathodic arc, and the DLC coatings be studied more extensively in a separate follow-on program to obtain more statistically valid results.
- Producing a Justification Report that documented the technical justification of the alternatives that were recommended for further investigation as well as cost data that were representative of the types of alternatives recommended.

Economic Analysis
In addition to the environmental concerns that are associated with EHC, issues that are related to long-term maintainability and reliability of DoD systems must be considered. Reductions in funding for national defense has necessitated continued operation of aging propulsion systems in aircraft, ships, and certain military vehicles. Although EHC has been an accepted practice for many years for gas turbine engine repair, chromium is not necessarily the best material/process in terms of cost and mission effectiveness.

Each of the demonstrated PVD systems shows improved wear performance over EHC plating in coupon tests. This improvement is expected to increase part service life (i.e., the maintenance to rebuild worn parts, restore dimensional tolerance, and replace a worn or damaged coating, such as hexavalent chromium, would occur less frequently). Extended service life can lead to a decrease in total cost-of-ownership through engine overhaul cycle and labor hours and improved weapon system readiness. In addition, none of the investigated alternatives have to bear costs similar to the costs of waste disposal and regulatory compliance that are associated with hard chromium.

Suggested Implementation Applications
PVD technologies are particularly useful on parts that only use the bare substrate or for components that require a thin dense chrome coating. The NDCEE has investigated PVD processes for use on a variety of weapon system parts, including M1 intermediate and anti-friction, bearing housings; helicopter drive shafts and gear scuff samples; duo cone seals for Marine Amphibious Assault Vehicles; and B-2 Bomber bomb door hinges.

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Applicable NDCEE Task
Pollution Prevention Initiative (Task N.227)

Plasma-Assisted Chemical Vapor Deposition

The NDCEE has demonstrated and evaluated the feasibility of using Plasma-Assisted Chemical Vapor Deposition (PACVD) to deposit diamond coatings on Inconel 718 and 4340 steel substrates. The NDCEE has determined that the process could be a viable surface protection replacement for EHC in terms of wear resistance on 4340 steel, but additional testing is recommended prior to implementation by a DoD repair facility. Because diamond coatings are expected to degrade at the temperatures that are experienced in service by the components that are made from Inconel 718, the NDCEE does not recommend it for that substrate material.

Technology Description

PACVD is a surface protection technique that combines the good adhesion properties of chemical vapor deposition with the low temperatures of plasma vapor deposition while avoiding their typical drawbacks (high temperature with deformation and poor adhesion). PACVD is used for the application of thin film coatings and particularly for the deposition of diamond films.

PACVD equipment typically consists of two units. The first unit contains the electronic controls, and the second unit contains a vacuum chamber, pumps, gas flow controllers, and radio frequency (RF) matching unit. Up to four gases can be introduced. The system may be operated in manual, semi-manual, or fully automatic mode. In the process, components are cleaned first using an inert gas such as argon. The components are placed on an electrode that is "capacitively" coupled to a RF source. The inert gas is introduced into the chamber and ionized by the RF field, producing plasma. The positively charged ions of the plasma bombard and clean the substrates. The cleaning stage then is followed by the deposition stage in which a carbon-containing gas, such as acetylene, is introduced to provide the energetic carbon ions.

Technology Benefits and Advantages

- Improves safety and worker health conditions due to the reduction or elimination of hexavalent chromium
- May reduce the operational costs and labor requirements as a result of extending the service life of components
- Reduces waste generation
- Can extend wear life of original components and reduces maintenance costs
- Is amenable to batch processing

DoD Need

Surface protection and corrosion control

Service Need Numbers

Army: 3.1.c

Navy: 2.I.01.g, 3.I.03.e, 3.I.04.h

Technology Limitations

- High capital costs
- Extensive training required for operators

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with demonstrating selected EHC alternatives, including PACVD. Activities included:

- Producing a Demonstration Plan that outlined the activities that are necessary to demonstrate selected EHC alternatives, including PACVD, and the test methods and procedures that are used to evaluate the coatings and surface modifications. The alternatives had been identified in an FY00 Potential Alternatives Report for Ion Beam and Plasma-Based Alternatives to Chrome Plating of Gas Turbine Engine Parts.

- Demonstrating the feasibility of using PACVD to deposit a DLC coating for DoD propulsion applications. The demonstration was performed at a vendor facility.
- Performing corrosion, wear, adhesion, and nanohardness tests on deposits in accordance with the NDCEE Demonstration Plan to screen alternative coatings.
- Producing a Demonstration Report that documented the results of the demonstration/validation activities to determine the effectiveness of PACVD. Based on the overall test results, DLC coatings that are deposited via PACVD performed better in terms of wear resistance on 4340 steel than EHC. However, the steel panels were not tested at the highest loads on IN718 because they are expected to degrade at the temperatures that IN718 components often experience in service.
- Producing a Justification Report that documented the technical justification for recommending PACVD for further investigation.

Economic Analysis
In addition to the environmental concerns that are associated with EHC, issues related to long-term maintainability and reliability of DoD systems must be considered. Reductions in funding for national defense has necessitated continued operation of aging propulsion systems in aircraft, ships, and certain military vehicles. Although chromium plating has been an accepted practice for many years for gas turbine engine repair, chromium is not necessarily the best material/process in terms of cost and mission effectiveness.

PACVD showed improved wear performance over EHC in coupon tests. This improvement is expected to increase part service life (i.e., the maintenance to rebuild worn parts, restore dimensional tolerance, and replace a worn or damaged coating, such as hexavalent chromium, would occur less frequently). Extended service life can lead to a decrease in total cost-of-ownership through engine overhaul cycle and labor hours and improved weapon system readiness. In addition, this alternative should have lower waste disposal and regulatory compliance costs than those that are associated with hard chromium.

Suggested Implementation Applications
PACVD is used for many mechanical-tribological applications where parts, such as those found in engines, require a low coefficient of friction and high wear resistance. PAVCD-applied diamond coatings also are commonly used in medical devices as well as electronics. Diamond coatings can be applied to a wide range of metals, ceramics, glasses, and plastics.

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Applicable NDCEE Task
Pollution Prevention Initiative (Task N.227, Mod 1)

Portable Munitions Monitoring System

The NDCEE, in conjunction with the Physical Science Laboratory at New Mexico State University, is facilitating the development of an improved generation of munitions monitoring systems. As part of the development process, several application and production issues were addressed, including conducting noise level, temperature, and random motion measurements as well as adhesive and fiber splice testing. For instance, tests were conducted to determine which adhesives are compatible with the sensors while providing the required bond properties. Adhesive compatibility is an issue because optical fibers nearly always are coated with a polymer material to improve their ease of handling.

Technology Description

The Portable Munitions Monitoring System (PMMS) is being designed to constantly measure the temperature and dimensional changes of munitions in storage and transit. Still in development, the system would replace the current predictive technology approach, which characterizes the storage conditions of a product and then predicts the product's degradation using models. These models may be based on either knowledge of the inherent degradation processes or on empirical data. Often, once a product passes a certain threshold that is based on the measured storage conditions, it is removed from inventory. A similar approach is the use of lot testing in which representative samples of each production lot are removed from storage for functional testing. If the units pass the storage conditions threshold, the entire lot is removed from inventory.

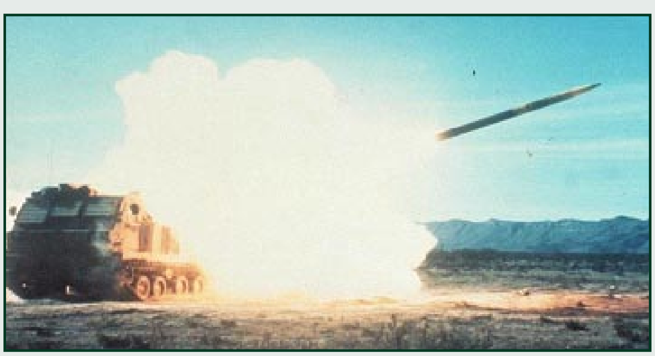
The key element of the PMMS is the use of the fiber Bragg grating (FBG) sensor technology. This optical technology can measure mechanical strain and temperature in a variety of situations. Consequently, rather than merely monitoring the storage conditions to which products are subjected, it may be feasible and cost-effective to monitor the underlying physical properties that are a direct indicator of possible product failure. Approaches to using them to measure other physical parameters (e.g., pressure, shock, acceleration, and concentrations of certain gases) are under development.

DoD Need

Improved monitoring technique of munitions in storage and transit

Army: 3.3.c

As part of the evaluation process, a munitions test fixture was designed to test the FBG in a configuration that closely resembled a 155-millimeter projectile. The test fixture consisted of nine pieces that were machined from low-carbon steel. One of the pieces was the test specimen, a 5.5-inch tall cylinder of aluminum, with a 6-inch outer diameter, and a wall thickness of 0.058 inches. The test specimen was instrumented with three FBG sensors. Various experiments showed that the sensors could be used to measure the amount of deformation occurring in a test specimen. In addition, extensive trials have been conducted in which the PMMS continuously monitored temperature and strain with tens of sensor elements for periods of weeks.



The Portable Munitions Monitoring System is being developed to constantly evaluate the structural integrity of munitions in storage

Technology Benefits and Advantages

- Measures mechanical strain and temperature (with other physical parameters in development) in a variety of situations
- Provides immunity to radio frequency and electromagnetic interference due to the FBGs being entirely optical
- Obtains strain measurements that are better than those that are obtained with resistive strain gauges in terms of noise, repeatability, and stability

- Contains many sensors multiplexed on a single fiber, so that the "wiring" is simplified and cost per measurement is lowered
- Does not require electrical current at the measurement site (particularly beneficial to applications that involve explosives)
- Detects small dimensional changes, which are measured in terms of microstrain

Technology Limitations

- Still under development

NDCEE FY03 Accomplishments

- Designed and modified the PMMS carrying case to better cope with the real-world operating environment by enhancing cooling and internal components and shock mounting.
- Categorized FBG sensors with respect to their noise floors.
- Implemented a remote dial-up capability so that the PMMS software can access remote sensor arrays. This capability has two possible scenarios. The first allows the system to automatically download its data files at a given time interval. The second permits a remote computer to dial into the system and give it commands to download data files or retrieve the data files directly. To facilitate data collection from locations with various access methods, Internet and dial-up data collection have been implemented.
- Developed new test fixtures to further define the capabilities of the system.
- Performed thermal cycling experiments on unattached FBGs with the PMMS. These experiments showed that the system could reliably monitor and record data under highly transient conditions (e.g., systems in transit).
- Produced a test plan for the FY04 field demonstration of the PMMS in which two types of rocket motor assemblies will be instrumented with FBGs and their progress monitored for a period of time. The NDCEE team will conduct the tests in conjunction with the Navy Magazine and Missile Assembly Facility at White Sands Missile Range.

Economic Analysis

Under current munitions monitoring applications, products that should be removed from inventory may not be discovered and/or products are removed unnecessarily. This situation can result in preventable production and disposal expenses as well as increased worker safety and health risks associated with replacing and disposing of products that are removed unnecessarily. Conversely, increased expenses, worker risks, and risks to soldiers in the field can occur with undetected product failures.

Suggested Implementation Applications

The munitions monitoring system is being developed to evaluate the structural integrity of munitions in storage and transit.

Points of Contact

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Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R2-14)

Powder Coating

The NDCEE has extensive technical expertise with powder coating. The technology is an integral aspect of the NDCEE Demonstration Facility where it has been used for nearly a decade by DoD and industrial facilities to explore the technology's viability for their site-specific needs. Once the technology has been validated to be technically and economically beneficial for a facility, the NDCEE provides implementation and training assistance to the facility. Most recent beneficiaries of NDCEE powder coating knowledge have been Tobyhanna Army Depot, Rock Island Arsenal, and Lake City Army Ammunition Plant. Past recipients have included Corpus Christi Army Depot, Naval Air Depot–Jacksonville, and the Joint Group on Pollution Prevention.

DoD Need

Environmentally compliant coating system

Service Need Numbers

Air Force: 100-189, 214, 237; 200-307, 331; 800-837; 1200-1261; 1600-1648; 1700-1756, 1773, 1794

Army: 2.1.h, 3.2.j

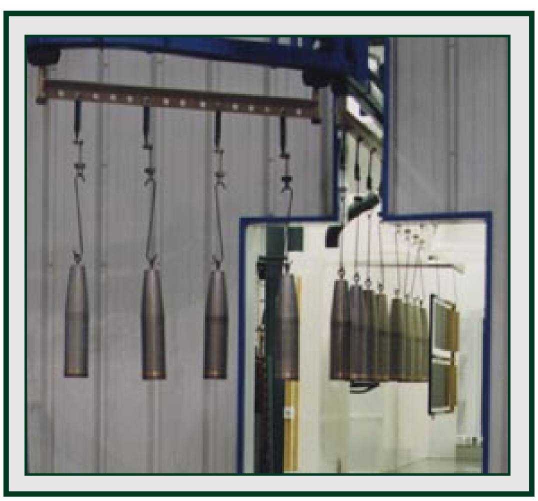
Navy: 2.1.01.g, 3.I.04.e, 3.I.04.h

Technology Description

Powder coating technology is an environmentally friendly alternative to the use of conventional solvent-based, waterborne, or high-solids painting processes. It provides a durable coating and reduces operating costs while eliminating HAPs, VOCs, and solvents. The four basic powder coating application methods are electrostatic spraying, flame spray, fluidized bed, and electrostatic fluidized bed. Electrostatic spraying is the most frequently used method. For all four methods, surface preparation (i.e., cleaning and conversion coating) is required to develop a good coating adhesion substrate. Characteristics of each method are described below.

In *electrostatic spraying*, an electrical charge is applied to the dry powder particles while the component that is to be coated is electrically grounded. The charged powder and grounded workpiece create an electrostatic field that attracts and holds the paint particles to the workpiece. The coated workpiece is placed in a curing oven where the paint particles are melted onto the surface, fused into a film, and then chemically crosslink into a cured film.

The *flame-spray* technique was developed primarily for application of thermoplastic powder coatings. After being fluidized by compressed air, the thermoplastic powder is fed into a flame gun where it is injected through a flame of propane, melting the powder. The molten coating then is deposited on the workpiece, forming a film on solidification. Because no direct heating of the workpiece is required, this technique is suitable for applying coatings to most substrates, including metal, wood, rubber, and masonry. It also is useful for coating large or permanently fixed objects such as steel frames, railcars, and large diameter pipes.



Automated powder application to 105-millimeter artillery projectiles

In a *fluidized bed*, an air stream keeps powder particles in suspension until they come in contact with a preheated workpiece, at which point, they melt and adhere to the workpiece surface. Coating thickness is dependent on the temperature and heat capacity of the workpiece and its residence time in the bed. Typically, post heating is not required to cure thermoplastic powder coatings, but it is required to cure thermoset powder coatings completely.

With *electrostatic fluidized beds*, the air stream is electrically charged as it enters the bed. The ionized air then charges the powder particles, which cover the grounded workpiece as it enters the chamber. Unlike with the conventional fluidized bed, this technique does not require a preheated workpiece, but curing of the coating is necessary. This technology is most suitable for coating small objects with simple geometry.

Powder coatings are individually formulated to meet specific finishing needs (e.g., desired properties) and fall into two basic categories: thermoplastic and thermosetting. Generally, thermosetting powders use epoxy, polyester, and acrylic resins and are more suitable for thicker coatings, providing increased durability. Thermoplastic powders are often used when comparatively thin coatings are desired such as decorative coatings. They primarily contain polyethylene, polyvinyl, nylon, and fluoropolymer resins.

In comparison to conventional painting techniques, powder coating provides improved safety and working conditions as well as cost savings in labor, materials, handling, and disposal of waste. It eliminates most waste streams, such as spent cleaning solvents, air emissions, and waste streams, that are generated from air emission control equipment. Cleanup time is faster because the powder is dry when sprayed, allowing overspray to be readily retrieved and reclaimed for reuse. Consequently, powder usage efficiency can approach 98% because the overspray powder is separated from the air stream by various vacuum and filtering methods and returned to a feed hopper for reuse.

Technology Benefits and Advantages

- Eliminates the use of VOCs and HAPs that are used as typical solvents in liquid paints and thereby eliminates hazardous air emissions
- Improves worker health conditions and minimizes safety risks
- Can be implemented in high-production facilities with highly automated application systems or on low-volume, manual-batch applications
- Results in nearly 98% usage efficiencies because overspray can be captured and reclaimed
- Can use specialty coating formulations that provide powder coating cure by high-intensity infrared exposure and thermal melt/ultraviolet-crosslinking film formation
- Reduces booth ventilation energy requirements by recycling spray booth air instead of venting to the atmosphere to remove solvent emissions
- Provides significant cost savings in labor, materials, and handling and disposal of waste
- Provides protection as a barrier if primers or pretreatments are not used, and prevents corrosion as long as the coating remains intact and undamaged

Technology Limitations

- As with other coatings, adequate booth ventilation must be maintained to eliminate explosion hazards (accumulation of suspended particulate). Integrated application equipment controls and fire sensors significantly limit these risks.
- System configurations are partially application-specific, but not severely limited.
- Depending on the coating requirements some applications may be restricted by complex geometry and component assembly.
- Typically, workpieces that can be oven heated to 400°F (204°C) are suitable for powder coating application methods. The temperatures that are required to cure the coating are too high for many materials that are used in aerospace structures (primarily aluminum and magnesium); however, recently developed formulations allow baking as low as 250°F (121°C), which enables the use of powder coating on most materials. Also, infrared flash cure powder coating technology has been developed for curing more sensitive substrates (i.e., materials that must be baked at less than 180°F) or, conversely, for rapid curing of high volume parts production such as small caliber ammunition projectiles.

NDCEE FY03 Accomplishments

The NDCEE developed a powder coating line specification for TYAD that is based upon the facility's needs, available space, and support of new maintenance activities and processes. The NDCEE tested and evaluated two colors for TYAD. Under an earlier evaluation, the NDCEE tested 24533 green powder, which TYAD approved for implementation. Upon conclusion of the evaluation and assuming successful findings, the NDCEE will help to purchase and implement a powder coating system at TYAD. As part of the line specification process, the NDCEE will conduct a cost-benefit analysis to ensure implementing the powder coating technology is a sound fiscal decision. During implementation, the NDCEE is planning on providing application training, quality tools development, and equipment start-up services.

Economic Analysis

The typical capital costs for a powder coating system can range from $20,000 to greater than $4 million. The NDCEE performed a cost analysis to determine the maximum capital expenditure that would be allowable for LCAAP to stay within a three-year payback period. LCAAP was considering using powder coating for bullet tips. For that payback period, the equipment, installation and facility modification costs had to be no more than $360,000, which is much less than the cost of a typical powder coating installation. The 15-year value was calculated to be $396,111 and the IRR was 54%.

Suggested Implementation Applications

Powder coatings are commonly used on a wide assortment of products from ammunition to park benches to automobiles. To ensure that powder coating is their best coating option, DoD production and maintenance coating facilities should conduct a technical and economic evaluation prior to implementation.

Points of Contact

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Applicable NDCEE Task

Sustainable Green Manufacturing (Task N.301, Subtask R3-8)

Pulsed High-Voltage Aluminum Ion Vapor Deposition Process

The NDCEE has demonstrated and evaluated the feasibility of using a Pulsed High-Voltage Aluminum Ion Vapor Deposition (IVD) Process. DoD repair depots commonly use IVD to provide surface protection of components.

DoD Need

Surface protection and corrosion control

Service Need Numbers

Air Force: 200-311, 900-1952

Army: 3.1.c

Navy: 3.I.03.e, 3.I.04.e

Technology Description

Conventional IVD is used to apply sacrificial aluminum coatings on metallic parts as an alternative to zinc or cadmium plating. The IVD process is performed in a chamber that is evacuated to a pressure in the 10^{-5} Torr range by a series of vacuum pumps. During the process, the aluminum is vaporized using resistive methods, and the parts are biased negatively, which attracts ionized coating material as well as ions from the gaseous plasma towards the parts.

After deposition, the coating is glass-bead-peened to test adhesion and provide an even denser surface for improved corrosion protection. The parts are then immersed into a chromate conversion coating solution and rinsed in hot water. The pretreatment imparts greater corrosion resistance and lubricity and provides a surface that is amenable to painting.

ISM Technologies, a division of Cutting Edge Products, Inc., in conjunction with the former McDonnell Douglas Aerospace (now part of the Boeing Company) developed an improved IVD aluminum process as an alternative coating system to prevent large capital investments in new systems while reducing environmental impact and production costs. The process is implemented by retrofitting existing IVD aluminum chambers with a pulsed high-voltage (10 kilovolt) power supply. The pulsed high-voltage bias is applied to parts. Because the bias is greater than in conventional IVD, the ions are attracted and accelerated at greater velocities. Therefore, more momentum is transferred to the depositing coating, resulting in the collapsing of coating voids, which theoretically leads to a denser aluminum coating. In tests that were performed by ISM Technologies, the resulting IVD coating, when combined with conventional chromating processes, showed significant improvement in corrosion resistance over conventional chromated IVD deposits when a 1-mil aluminum coating was applied. Because chromate solutions use hexavalent chromium, a class one human carcinogen, nonchromate processes are being evaluated with the new IVD process, with and without the glass-bead peening process.

Technology Benefits and Advantages

- Causes no reduction in product quality or part throughput in comparison to present processes
- Reduces material and operating costs because glass-bead peening is eliminated and less hazardous waste is generated/disposed
- Reduces worker health and safety risks by eliminating the use of hexavalent chromium

The Pulsed High-Voltage Aluminum IVD Process may help to reduce corrosion on DoD weapon systems.

- Can be retrofitted onto existing IVD processes; thereby, avoiding large capital investment costs

Technology Limitations

- As with conventional IVD processes, the technology has line-of-sight limitations.

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with identifying and evaluating alternatives to chromium-bearing solutions that are used in plating operations, metal stripping, and other finishing processes applications. Activities included:

- Conducting a demonstration on the Pulsed High-Voltage IVD Aluminum Process using five nonchromate coatings: Alodine 2600 by Henkel Surface Technologies, 168 and 605 Processes by Natural Coating Systems, Full Process by Sanchem, Inc., and a trivalent chromium pretreatment (TCP) that was developed by NAVAIR.
- Producing a Demonstration Report that detailed the demonstration results. Demonstration data provided contradictory evidence, with two studies suggesting that the improved IVD process provided better corrosion protection and one favoring the conventional process. The only consistent trend was that NAVAIR's TCP with color provided adequate corrosion protection, with and without peening. Based on these findings, additional work is required to further optimize the process to produce coated test panels with repeatable results.
- Producing a Justification Report that documented the findings of a cost-benefit analysis for using conventional IVD (with and without glass-bead peening) with a nonchromate treatment. Baseline costs were obtained from Oklahoma City Air Logistics Center.

Economic Analysis

Because the pulse IVD did not show a performance improvement, an ECAM℠ analysis was not performed on the technology. However, the NDCEE conducted an economic analysis to measure the financial feasibility of implementing the TCP conversion coating in conjunction with a conventional IVD process. The analysis revealed that use of conventional IVD followed by TCP is effective at offering improved corrosion protection at OC-ALC. The analysis also indicated that overall operating costs would remain the same if glass-bead peening was used with TCP. The finding suggests that other DoD repair depots that are using IVD aluminum coatings should obtain similar results.

Other nonquantifiable benefits also were identified that favor implementation. These benefits include the elimination of worker exposure to the carcinogen, increased ability (and possible reduced costs) to meeting present or future OSHA exposure limits for hexavalent chromium, reduced shipping and storage hazards, and simplified requirements for treatment of the process wastewater.

Suggested Implementation Applications

Any location with conventional IVD systems would be a potential implementation site. Applicable weapon systems include M-80, M60, M48 (ANAD); CH 60, F-15, F-18 (NADEP-JAX); and B52H, C141, E3, KC135, C18, E8 (OC-ALC).

Points of Contact

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Applicable NDCEE Task

Pollution Prevention Initiative (Task N.227)

"Smart-Pipe" Infrastructure Analysis

The NDCEE conducted a project to research, develop, demonstrate, and validate intelligent systems for water and wastewater conveyance and storage infrastructures. The project goal was to determine the most practical and cost-effective method for monitoring the health of commonly used materials and sizes of pipes and storage vessels. Consideration also was given to the compatibility of the new technology with existing water and wastewater systems.

Technology Description

The "smart-pipe" technology is a developing technology area that will provide ongoing, real-time evaluations on the structural health of pipelines or storage tanks using nonintrusive or nondestructive methods. To detect and locate a weakening infrastructure, the ideal system will be fully automated and provide remote monitoring and reporting on pipe wall thickness or strength changes as well as unacceptable loading conditions outside or inside the pipe. The information will provide the basis for optimizing maintenance planning and preventing infrastructure failures and their attendant health, environmental, and economic hazards.

The state-of-the-art in leak detection is primarily based on acoustic emission, whereby acoustic sensors detect the energy that is released from a leaking fluid to locate a leak and estimate its leakage rate. In addition, the analysis of pressure waves that are generated during a sudden change in fluid flow rate has also been used for leak detection and location. Both of these methods are well established and have been used for leak testing, the transport and storage of hazardous materials, and to some extent by water utility managers. However, their ability to measure structural weakening prior to actual leakage is currently limited.

The NDCEE identified the following four emerging technologies as potentially able to locate structurally weak areas and predict incipient leaks.

Distributed piezoelectric sensors: These sensors utilize the piezoelectric effect to detect vibrations in rigid structures. Discovered in 1880, the piezoelectric effect is exhibited in some crystalline solid materials that have unit cells without a center of symmetry. These materials, when mechanically stressed, produce an electrical charge. Conversely, when an electric field is applied, they produce a mechanical strain that changes the dimensional shape of the material. At present, distributed piezoelectric sensors for smart pipes are made of thick film sensors, piezoelectric composites, piezoelectric polymers or piezometric paint.

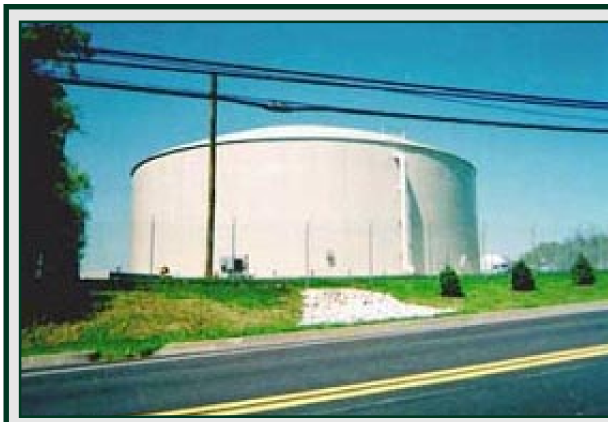
DoD Need

Improved methods for wastewater and drinking water infrastructure monitoring and maintenance

Service Need Number

Army: 2.2.f

Instrumented cathodic protection (ICP): A proven electrical technique, ICP is used to prevent metal structures from corrosion through one of two methods. The first method consists of coupling a structural metal (e.g., iron) with a more active metal (e.g., zinc or magnesium), which becomes a sacrificial anode. The second method involves impressing a direct current between an inert anode and the structure that is to be protected. By using the current, another oxidation process, besides corrosion, occurs at the anodes, and the anodes are not consumed. ICP is primarily used in metallic structures that are buried in soil or submerged in water such as is the case with underground utility distribution piping, underground fuel storage tanks, elevated water storage tanks, and navigational structures.



The "smart-pipe" technology is being developed to help monitor storage tanks as well as drinking water and wastewater infrastructures.

Electrically conducting composite pipes (ECCP): ECCPs use materials that employ the electrical resistance technique, which relies on changes in electrical resistance, or of potential distributions in the laminate, to characterize a damaged structure. This method allows the entire structure to be monitored, whereas the use of embedded or attached sensors tends to restrict monitoring to only selected positions. It is particularly effective for detecting small and subtle material defects in composite structures. A prototype version of the technology was patented by Anderson Consulting on January 3, 1995. This version uses a layer of conducting material, in this case, a conducting fabric, as the sensing layer. It can be adapted by one of two ways. It can be inserted as a separate liner or sleeve into old existing pipes or the old pipes can be replaced with new pipes (the recommended method).

Electrochemistry-based corrosion sensors: These sensors are based on electrochemical impedance spectroscopy (EIS). They provide very detailed data on the effectiveness of a coating over a relatively small area of less than a square foot. The EIS technique can indicate the presence and rate of corrosion, and the moisture content of the coating prior to corrosion. EIS measurements consist of applying an alternating voltage (5–10 millivolts) to the corroding metal, and measuring the impedance to account for both the magnitude and the relative phase angles of the voltage and current. *In-situ* EIS sensors can monitor or inspect corrosion of boiler tubes, buried pipes, coated steel structures, and, potentially, composite/metal structures.

Technology Benefits and Advantages

- The developing technology area will monitor and improve the predictive maintenance of a wastewater and drinking water infrastructure and storage tanks.
- Although not yet proven, the driver is to reduce environmental costs as well as reduce overall installation and maintenance costs.
- Depending on the technology, it may detect material flaws, wall thinning, loss of structural integrity/joints, and loss of protective coating.

Technology Limitations

- Some methods may be applicable for one specific type of pipe material [e.g., steel pipe or prestressed concrete cylindrical pipe (PCCP)], while others may be applicable to all materials.
- Some technologies are applicable to pipes of all sizes, while others may only be applicable to small diameter pipes.
- None of the technologies can detect temperature loads.

NDCEE FY03 Accomplishments

The NDCEE produced a Final Report that documents the results of its investigation on emerging smart-pipe technologies and factors that affect the health of infrastructures. During this two-year investigation, the NDCEE conducted a state-of-the-art literature review and identified four emerging technologies that can potentially locate structurally weak areas and predict incipient leaks. In addition, the NDCEE determined the technical approaches that are required for integrating smart technology into the conveyance and storage infrastructure. Input was solicited from utilities and other relevant sources of expertise (e.g., pipe manufacturers) regarding the findings of the smart-pipe method(s) and technologies.

Economic Analysis

The United States has about 863,000 miles of pipeline, with about 11,900 miles of new pipes added each year and approximately 4,100 miles of pipeline replaced annually. Because maintaining system integrity can be very painstaking and costly, drinking water distribution companies are constantly looking for technologies that will upgrade and maintain the high quality of service that is provided to consumers.

While the initial capital cost is important, the ongoing costs of operating the pipeline can far outweigh any "savings" that are made by selecting a pipeline system, which may have a low installation cost, but a high risk of failure and a limited working life. Life-cycle costing of alternative pipeline systems will enable service providers to select the most economic solution and provide water at the lowest cost per gallon to the consumer.

Suggested Implementation Applications

The technology would be suitable for any site that must monitor its drinking water or wastewater infrastructure. In addition, it would aid sites with storage tanks that must be monitored for leakage.

Points of Contact

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Applicable NDCEE Task

Research, Development, Demonstration and Validation of Intelligent Systems for Conveyance and Storage Infrastructure (Task N.246)

NDCEE Evaluation of Emerging Smart-Pipe Technologies

	Piezoelectric Sensors	EIS Sensors	ICPs	ECCP (Anderson version)	Acoustic emission sensors	ECCP (as a sleeve)
Fully Automated Operation						
Local transducer	Y	Y	Y	Y	Y	Y
Central collection	N	N	Y	N	Y	N
Data analysis	N	Y	Y	N	Y	N
Alarm	N	Y	Y	Y	Y	Y
Feedback	N	N	N	N	N	N
Monitoring & Reporting						
Remote	N	N	Y	N	Y	N
Continuous	Y	Y	Y	Y	N	Y
Real time	N	Y	Y	Y	Y	Y
Compatible	Y	N	Y	Y	N	Y
Reporting	N	N	Y	N	N	N

NDCEE Evaluation of Emerging Smart-Pipe Technologies (continued)

	Piezoelectric Sensors	EIS Sensors	ICPs	ECCP (Anderson version)	Acoustic emission sensors	ECCP (as a sleeve)
Pipe Failure/Pre-Failure						
Material flaws	N	Y	N	Y	N	Y
Wall thinning	Y	Y	Y	Y	N	Y
Loss of structural integrity/joints	N	N	N	Y	N	N
Loss of protective coating	N	Y	Y	Y	N	Y
Temperature-induced loads	N	N	N	N	N	N
Adaptability/Acceptability to Existing Drinking Water/Wastewater Systems						
Size	Y	Y	Y	Y	Y	Y
Materials	Y	Y	N	Y	N	Y
Life expectancy	N/A	N/A	Y	Y	Y	Y
Joints and connections	Y	N/A	N	N	N	N
Repair/installation/fabrication	N/A	N/A	Y	Y	N	Y
Implementation						
Capital	N/A	Extremely High	Moderate	High	Low	Low
Operation costs	N/A	High	Moderate	Low	Low	Low
Commercial availability	N/A	N	Y	Y	Y	N
Predictive Capability						
Alert when repair or replacement is required before any system breach or failure occurs	Y	Y	Y	Y	Y	Y
Indicate general location of failure	Y	Y	Y	Y	Y	Y
Provide the remaining service life	N	N	N	Y	Y	Y
Alert when catastrophic failure occurs	Y	Y	Y	Y	Y	Y
Data						
Laboratory-scale	N	Y	Y	Y	Y	Y
Field-scale	N	Y	Y	Y	Y	Y
Installed systems	N	N	Y	Y	Y	Y
Limitations						
No Material Limitations	Y	Y	N	Y	N	Y
No Size/Area Limitations	Y	N	Y	Y	Y	Y
Summary						
Total no. of Ys out of 30	12	16	22	23	16	21
Notes:	Still in development stage	If Combined with ECCP	Only works with metal pipes	Best and most cost-effective	Only applies to PCCP	

N/A= Not applicable

Sodium Bicarbonate Blasting

Under previous efforts, the NDCEE and Naval Surface Warfare Center, Carderock Division tested alternatives, including sodium bicarbonate blasting, to current coatings removal and etching methods at the NDCEE Demonstration Facility. The NDCEE utilized these efforts to help to identify potential alternatives to chemical or mechanical coatings removal processes for use on delicate substrates, many of which are also dimensionally critical parts.

Technology Description

Sodium bicarbonate stripping processes can be used as alternatives to traditional chemical paint strippers, hand sanders, and manual cutting tools. Sodium bicarbonate (also known as bicarbonate of soda) is a soft blast medium with a higher specific gravity and less hardness than most abrasives. The effectiveness of sodium bicarbonate depends on optimizing a number of operating parameters, including nozzle pressure, standoff distance, angle of impingement, flow rate, and traverse speed. This process can clean and depaint such items as stainless steel, aluminum, galvanized metal, concrete, ceramic tile, glass, plastics, fiberglass, rubber, and neoprene.

The process can be used with or without water. It is most frequently used with water, which acts as a dust suppressant. In this form, compressed air delivers sodium bicarbonate media from a pressure pot to a nozzle, where the media mixes with a stream of water. The soda/water mixture impacts the coated surface and removes old coatings from the substrate. The water dissipates the heat that is generated by the abrasive process, reduces the amount of dust in the air, and assists in the paint removal by hydraulic methods. Workers do not need to prewash or mask the surface of the material that is being stripped. Settling or filtration can separate the solid residue that is present in the wastewater.

The use of sodium bicarbonate in its dry form (or when not fully mixed with water) can create a cloud of dust that will require monitoring and may require containment to meet air standards. Though the dust that is generated is not an explosive hazard, the airborne particulates that are generated from the stripping operation can contain toxic elements that are found in the paint being removed. This stripping process should be performed in areas where exhaust particulates can be contained and/or exhaust ventilation system controls are present to remove hazardous airborne metals.

DoD Need

Environmentally preferred coatings removal technique

Service Need Numbers

Air Force: 100-202, 213, 221, 298; 200-304, 309, 322, 327, 332; 900-2095; 1600-1646; 1700-1754, 1758

Army: 2.1.h, 2.3.k, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

Technology Benefits and Advantages

- Eliminates the use of chemical strippers
- Reduces labor and operating costs as a result of decreased preremoval preparation and postremoval cleanup

Technology Limitations

- Wastewater and waste solids must be analyzed to determine disposal requirements.
- Media cannot be recycled.
- The use of sodium bicarbonate in its dry form (or when not fully mixed with water) can create air emissions that will require monitoring and may require containment to meet air standards.
- If the operating temperature of the part is at or above the temperature 140–160ºF (60–71ºC), the residual sodium bicarbonate may become corrosive.

At NAB Little Creek, the NDCEE successfully field demonstrated wet sodium bicarbonate blasting on an aluminum HMMWV component.

- NAVAIR and the Air Force currently limit the use of sodium bicarbonate stripping to specific approved applications that have no possibility of trapped residual sodium bicarbonate.

NDCEE FY03 Accomplishments

- Conducted field demonstrations on four coating removal processes on behalf of Fort Eustis and NAB Little Creek. Sponge, fiber, water, and wet sodium bicarbonate blasting were evaluated on their abilities to meet the facilities' production requirements and waste reduction needs. They also were tested on some delicate substrates to determine if the substrates would be damaged during the coating removal process.
- Produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with evaluating the feasibility of using sodium bicarbonate blasting for coatings removal. Based on demonstration findings that were documented in a Demonstration Report, the NDCEE recommended that further evaluations and testing of this alternative be conducted with advancements made to the containment devices.

Economic Analysis

Equipment costs range from $15,000 to more than $40,000. Although the NDCEE has not conducted a cost-benefit analysis, operating costs are expected to be substantially less than chemical stripping.

Suggested Implementation Applications

Potential applications include weapon system components such as PCMS tiles on submarines and radomes from ships and aircraft.

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Applicable NDCEE Tasks

Pollution Prevention Initiative (Task N.227, Mod 1)

Sustainable Green Manufacturing (Task N.301, Subtask R3-10)

Sponge Blasting

Under previous efforts, the NDCEE and Naval Surface Warfare Center, Carderock Division tested alternatives at the NDCEE Demonstration Facility, including sponge blasting, to current coatings removal and etching methods. The NDCEE utilized these efforts to help identify potential alternatives to chemical or mechanical coatings removal processes for use on delicate substrates, many of which are also dimensionally critical parts.

Technology Description

The sponge blasting technology cleans, etches, and removes coatings from various types of substrates. It uses an air-propelled open cell, water-based polyurethane foam cleaning media (also known as sponge media). The foam material can be impregnated with abrasive grit to enhance the performance of the media. The abrasive media may contain a variety of grit including aluminum oxide, steel, and plastic. The ability to use different media types gives the system flexibility by providing different characteristics and blasting capabilities. The foam cleaning media are absorptive and, when wetted with a cleaner or surfactant, can be used to remove a variety of surface contaminants and control dust without excess wastewater.

A feed unit is used to deliver sponge media to the surface. A media classifier is required to handle recycling chores. This classifier operates by collecting the sponge blast media and running the media through an electrically powered sifter, which separates the sponge media into four categories: oversized debris, reusable debris, reusable media, and fines (consisting of spent media and dust). Typically, 85–90% of the sponge media is reusable after each blast cycle. Using a classifier, the media can be recycled approximately 5–7 times for low dust applications. The amount of times that the media can be recycled depends on the type of surface and the contaminants that are removed from the surface. Some applications have shown up to 18 uses before the media are no longer productive.

Typically, the waste that is generated with sponge media blasting is minimal because the media are recyclable. The disposal method depends on the type of coating or substance that was removed from the surface. Generally, if the substance that is being removed is classified as nonhazardous waste, then the spent media and the material that were removed are placed into a drum and sent to a landfill. If the substance that is being removed is classified as a hazardous waste, such as a radioactive material or a lead-based paint, then it must be placed in an approved container (55-gallon drum) and sent to an approved disposal facility.

Technology Benefits and Advantages

- Decreases solid waste and eliminates the use of chemical strippers
- Reduces labor and operating costs as a result of decreased preremoval preparation and postremoval cleanup
- Improves safety and worker health conditions due to the elimination of airborne emissions of heavy metals and other contaminants when used with vacuum recovery
- Involves reusable media
- Helps facilities to comply with Executive Order 13148, which requires the DoD to decrease the amount of waste that is generated at federal facilities, as well as environmental regulations regarding airborne particulate emissions

DoD Need

Environmentally preferred coatings removal technique

Service Need Numbers

Air Force: 100-202, 213, 221, 298; 200-304, 309, 322, 327, 332; 900-2095; 1600-1646; 1700-1754

Army: 2.1.h, 2.3.k, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

Sponge media feed unit

Technology Limitations

- Not as aggressive on metallic substrates as some abrasive media. However, unlike the sponge medium, these more abrasive media do not have the capability to be used on delicate substrates.

NDCEE FY03 Accomplishments

- Conducted field demonstrations on four coating removal processes on behalf of Fort Eustis and NAB Little Creek. Sponge, fiber, water, and wet sodium bicarbonate blasting were evaluated on their ability to meet the facilities' production requirements and waste reduction needs. They also were tested on some delicate substrates to determine if the substrates would be damaged during the coating removal process. Based on test results, the NDCEE recommended sponge and fiber media blasting for implementation at Fort Eustis and water or fiber media blasting for NAB Little Creek. Results were documented in a Technical Report.
- Produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on NDCEE activities in connection with evaluating the feasibility of using sponge blasting for coatings removal. The NDCEE produced an Alternatives Report that identified the needs and requirements for alternative coatings removal technologies from delicate substrates. Sponge blasting was recommended for evaluation on HMMWV hoods.

Economic Analysis

Equipment costs are approximately $50,000. Using the baseline removal rate that was received from Fort Eustis on its dry sodium bicarbonate blasting process for aluminum and fiberglass components, a comparison was made with the sponge alternative technology. Test results show that the sponge technology offers a comparable strip time to the baseline of 4–5 hours, causes no damage to delicate materials, and emits little to no dust. Because of the comparable strip rates, associated labor costs should be the same as the baseline method. Reduced procurement and disposal costs are anticipated because the sponge media are recyclable. Procurement savings are dependent on the price of the raw materials.

Suggested Implementation Applications

Applicable weapon system components include fiberglass hoods on HMMWVs and other delicate substrates.

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Applicable NDCEE Tasks

Pollution Prevention Initiative (Task N.227, Mod 1)

Sustainable Green Manufacturing (Tasks N.301, Subtask R3-10)

Thermophilic (Biological) Process

The NDCEE has demonstrated and evaluated the feasibility of a pilot-scale Thermophilic (Biological) Process (TBP) plant at both the Milan Army Ammunition Plant and Iowa Army Ammunition Plant. Through these demonstration projects, the NDCEE determined that the process is technically sound and environmentally safe. Under optimized conditions, the process consistently degraded over 90% of the nitrobodies from loaded granular activated carbon (GAC). Currently, the NDCEE is investigating the ability of the TBP process to treat nitrate esters in wastewater that is generated by the Naval Surface Warfare Center, Indian Head Division facility. Positive results to date indicate that some nitrate ester wastewaters can be treated directly with the microbes that are associated with the TBP process, without the need for GAC loading. Degradation rates of greater than 90% have been reproduced.

Technology Description

TBP was developed to treat pink water, which is explosive-laden wastewater originating from two munition functions: 1) load, assemble and pack; and 2) demilitarization. The technology also has demonstrated control of discharges from DoD-wide ammunition processing operations such as the water-dry propellant extraction waste in the sumps of ammunition plants. Although additional research is required, the TBP process potentially could be adapted to treat explosives-contaminated groundwater and soils. Bench-scale demonstrations are in progress to evaluate the process's ability to treat wastewater containing nitrate esters.

TBP is a modification of the U.S. Army's present method of GAC regeneration systems. Currently, ammunition plants meet pink water discharge requirements by removing the contaminants using GAC adsorption systems. The explosive-laden GAC is either regenerated for reuse or incinerated for disposal. Under the present method, regeneration often does not achieve Army requirements, and the GAC must be disposed of as a hazardous waste. TBP utilizes the GAC to adsorb the explosives from the wastewater, followed by base hydrolysis and thermophilic (biological) regeneration of the GAC. The treated wastewater is sent to a wastewater treatment plant.

The process begins with the contaminated water flowing into the GAC adsorption system. The contaminants are first adsorbed onto the GAC, which has demonstrated a high affinity and capacity for nitrobody compounds. After an adsorption cycle, flow through the GAC column stops and recirculation of a regeneration solution starts. The GAC column is first heated to 176°F (80°C) for base (caustic) hydrolysis, and then cooled to 131°F (55°C) for thermophilic regeneration, inoculated with nitrate-degrading organisms, and aerated. The column becomes a bioreactor. Thus, nitrated compounds, concentrated by the previous adsorption step, are depleted, and the GAC in the column is regenerated. The bioreactor fluid, containing natural organisms and enzyme systems, passes to the industrial wastewater treatment plant. In the last step, the regenerated GAC column cools and is placed on stand-by.

Technology Benefits and Advantages

- Biodegrades most nitrobodies in explosives-laden wastewater and renders them nontoxic, according to results from toxicity testing using the Microtox® instrument
- Can be retrofitted to the existing GAC adsorption systems, with only minor modifications
- Requires less energy than other processes that are currently in use

DoD Need

Treatment of explosive-laden wastewater (pink water) and nitrate ester wastewaters

Service Need Numbers

Army: 2.2.a, 2.5.e, 3.3.c

Navy: 2.III.01.v, 2.II.01

Prototype TBP unit

- Is commercially available, economically viable, and environmentally safe
- Poses limited health and safety risks; however, several contaminants in the explosive-laden wastewater are dangerous and precautions should be taken
- Regenerates loaded GAC columns, *in situ*, avoiding the risks and losses that are associated with handling and incinerating and/or regenerating the spent GAC by combustion. Based on bench-scale studies investigating the degradation of nitrate esters, wastewater can be inoculated and treated directly with thermophilic microbes, thus completely eliminating the use of the explosive-laden GAC and any exposure hazards associated with handling it.

Technology Limitations

- Operator training is required.
- Capital costs may be substantial.

NDCEE FY03 Accomplishments

- Produced a Final Justification Report that documented that, under IAAAP's current level of production, the TBP unit would not be economically feasible for implementation at IAAAP at this time. However, if IAAAP increased its use of GAC by 4.5 times, then the payback period becomes reasonable (5 years).
- Conducted bench-scale testing of the TBP technology for the treatment of nitrate esters in wastewater that are generated by NSWC, Indian Head. Testing was conducted in accordance with a NDCEE-developed, Government-approved Test Plan and Environmental Health and Safety Plan.
- Produced a Final Report that documented and summarized bench-scale test results. The results indicated that direct treatment of the wastewater with the thermophilic microbes could degrade some of the nitrate ester compounds of interest to NSWC, Indian Head, specifically propylene glycol dinitrate (PGDN), 1,2,4-butanetriol trinitrate (BTTN), and N-butyl-2-nitratoethylnitramine (BuNENA). Results also indicated that treatment of four other nitrate ester species may be possible with further bench-scale studies. These species are 1,1,1-trimethylolethane trinitrate (TMETN), triethyleneglycol trinitrate (TEGDN), diethyleneglycol dinitrate (DEGDN), and nitroglycerine (NG). Additional studies may show that the use of GAC for concentration and disposal of the nitrate esters could be eliminated.

Economic Analysis

No other cost-effective alternatives to GAC adsorption systems were found that could treat the explosive-laden pink water. The capital cost to retrofit the TBP technology to an existing 20-gallons-per-minute system is approximately $230,000; however, this cost may be insignificant compared to that of conventional GAC adsorption systems. The TBP technology can be used for pink water remediation at an estimated cost of $10–$15 per 1,000 gallons treated. Competitive technologies were found to cost more than twice that amount.

Suggested Implementation Applications

The TBP technology was designed to treat pink water and potentially may be able to treat explosives-contaminated groundwater and soils. Pink water by definition is a RCRA K047 hazardous waste due to the presence of nitrobodies, including 2,4,6 trinitrotoluene (TNT), cyclotrimethylene-trinitramine (RDX), and cyclotetramethylene-tetranitramine (HMX). The exact composition of pink water is highly variable and dependent on process materials and operations. The maximum concentration of dissolved energetic-related pollutants in pink water is 200 parts per million. Statutes also mandate that pink water be treated prior to disposal.

In addition to facilities that are generating pink water, facilities manufacturing nitrate esters for Navy and Army weapon systems may be candidates for implementation. Current uses of nitrate esters include the production of PGDN for the MK 46/48/54 torpedo program, production of TMETN and TEGDN for the MK 46/48/54 warhead program, BTTN production for use in the Hellfire and Brimstone programs, and NG manufacture for various rocket and missile systems.

Points of Contact

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Applicable NDCEE Tasks

Sustainable Green Manufacturing (Tasks N.213 and N.301, Subtask R2-8)

Treatment of Spent GAC Containing Nitrate Esters Using TBP Technology (Task N.309)

Treatment-Train Approach for Small Arms Firing Range Soils

At a small arms firing range (SAFR) at Fort Dix, the NDCEE demonstrated and validated a treatment-train approach that involved particle separation followed by stabilization to reduce total and leachable lead concentrations from impact berm soils. This project processed 7,576 tons of lead-contaminated soil and reduced the total soil lead levels by an average of 93% and the leachable lead concentrations by more than 98%. Treatability studies were conducted to develop a total range excavation plan to separate those portions of the range that required particle separation and stabilization from areas that required only particle separation. Variations in soil structure, gradation, chemistry, and contaminant will result in recovery rates that are site- and cost-specific and cannot be universally applied. For instance, one site may contain a high level of leachable lead due to acidic soil conditions, while another site may contain predominately particulate lead due to more neutral soil conditions.

Technology Description

A modified placer-mining technique is used to separate particulate metals, such as spent bullets and bullet fragments, of a certain particle size from the range soils. If the purity of the recovered metal meets performance standards (i.e., greater than 90%), the recovered metals can be sent to a recycling facility. Depending upon the nonparticulate metal concentrations, the soil may undergo phosphate-induced metals stabilization.

DoD Need

Removal of particulate inorganics from soils

Service Need Numbers

Army: 1.3.e

Navy: 1.I.01.1, 1.I.04.j

Prior to performing the full-scale field demonstration, bench-scale treatability studies were conducted. The results of these tests indicated that site soils were composed primarily of sand-sized material, with an oversized fraction of plus No. 10-sieve size (0.0787-inch) material that contained the majority of the particulate metal as well as rock and vegetation. The deployed soil processing system consisted of several physical components that were integrated into one continuous process. The process featured a wash plant for size separation, a mineral jig for gravity separation of metal and nonmetal particles, a pug mill for mixing soils and stabilization materials, a water treatment unit for process water clarification and settling, a belt filter press for fines dewatering, water storage and management, and recovered metals management.

The treatment-train process began with excavation, removal, and stockpiling of firing range soils. Data that were collected during the treatability studies were used to develop a whole-site excavation plan so that portions of the range that did not require both particle separation and stabilization could be segregated from soils that would require both treatment processes. Of the 7,576 tons of processed soil, 1,824 tons (24%) required both particle separation and stabilization, while the remaining 5,752 tons (76%) only required particle separation to achieve treatment goals.

The NDCEE demonstration at Fort Dix showed that lead-contaminated range soils could be effectively treated in the field and the recovered metals could be recycled. In addition, because the hazardous contaminants were sent to a smelter for recycling, rather than shifted to a landfill, the potential long-term risks to human health and the environment were eliminated.

The soil from the stockpiles was fed into the plant through a grizzly feeder and conveyor to a water-based vibrating screen that was equipped with a No. 10-mesh (0.0787-inch) screen. The conveyor was equipped with a belt scale for recording the production rate and daily tons of soil that were processed as well

as a magnetic separator to remove large magnetic items. The plus No. 10 sieve-size fraction from the vibrating screen (consisting of rock, particulate metal and vegetation) was then conveyed into the gravity separation unit, which consisted of two parallel jigs that were operated in an alternate batch mode, with metal removed from each jig as required. The physically treated sand fraction was sent from the mineral jig to a dewatering screw and then discharged to a temporary storage area for removal by a loader to the treated soil stockpile. The recovered metal particles were piped to a bagging module, where they were put into one-ton Supersacks™.

The minus No. 10 sieve-size fraction from the vibrating screen (consisting of fine sand, silt, and clay) was conveyed to the pug mill where it was mixed with dewatered fines from the belt filter press and the stabilization material, as required, and then discharged to a treated soil stockpile. Process water from the vibrating screen deck and the gravity separation unit as well as water from the belt filter press was transferred to a clarifier where a nonhazardous, nonionic coagulant was added to settle the fine particle size material from the water. The settled fraction was then discharged to the belt filter press for final dewatering, with subsequent discharge to the pug mill for mixing and stabilization, with final discharge to the treated soil stockpile. Recovered water from the clarifier was reused within the plant.

Technology Benefits and Advantages

- Removes particulate contaminants from the soil rather than transferring them to a landfill; thus, potential long-term risks to human health and the environment are eliminated.
- Recovers metals that can be classified as a “recyclable material” under 40 CFR 261.6(a)(3)(iv) of RCRA and are not subject to the requirements for generators, transporters, and storage facilities of hazardous wastes specified in paragraphs (b) and (c) of 40 CFR 261.6. Therefore, the scrap metal that is recovered from the firing range soils does not need to be regulated or manifested as a hazardous waste during range processing activities or transportation to a smelter for recycling.
- Achieves some reduction in the volume of the hazardous wastes that are associated with the range soils, although it is typically less than 1%, depending upon the composition of the waste streams (i.e., heavy metal particle size and concentration). Corresponding benefits include reduced storage, handling, and shipping costs, in addition to increased life of landfills, because less waste will be disposed of at those facilities.

Technology Limitations

- Substantial initial investment in equipment and staff training is required.
- A thorough treatability study is required to determine whether physical separation would be technically feasible and cost-effective in reducing the total heavy metal concentrations of the soil, based on site-specific soil conditions and contaminant levels.
- Air, water, and other permits may be needed; however, the NDCEE demonstrations revealed air emissions met Clean Air Act standards and the process generated wastewater that could be recycled back into the system.

NDCEE FY03 Accomplishments

The NDCEE completed the full-scale field demonstrations and prepared a draft Soil Processing Report. The report documents the activities and contains the results of both the particle separation and the stabilization technologies. In this demonstration, the particle separation technology removed 10.6 tons of particulate lead (i.e., bullets and bullet

fragments) from 7,576 tons of lead-contaminated soils. The removed lead was sent to a smelter for recycling. The stabilization material immobilized the nonparticulate lead and reduced Toxicity Characteristic Leach Procedure extract lead concentrations by more than 98%, from more than 27 milligrams per liter (mg/L) to an average of 0.22 mg/L. Overall, total soil lead concentrations were reduced from 5,683 milligrams per kilogram (mg/kg) to less than 100 mg/kg.

Economic Analysis

Based on demonstration activities and accounting for a higher production rate, the NDCEE has conducted an economic analysis that projected full-scale particle separation costs for annually treating three adjacent SAFRs at Fort Dix. The minimum quantity of soil to be processed annually would be approximately 30,000 tons. The projected full-scale unit cost estimate is $60 per ton. For a long-term project that would include the physical processing of soils from all of the SAFRs at Fort Dix, the unit cost could be reduced further because the costs that are associated with mobilization/demobilization would become one-time events, which would be applied to the entire quantity of soil processed.

The baseline approach to manage SAFR soils is excavation and off-site disposal at an approved facility. Because the impact berm soils routinely qualify as a characteristic hazardous waste, RCRA requirements apply to the excavation, transportation and disposal of these soils. A comparison cost estimate for excavation and off-site disposal at a secure RCRA disposal facility that was prepared indicates that this unit cost is approximately $243 per ton. The difference between the projected full-scale physical separation unit cost estimate and the conventional excavation and off-site disposal unit cost estimate is $183 per ton. For a full-scale project that encompasses 30,000 tons, this differential represents a cost savings of approximately $5,490,000.

Suggested Implementation Applications

Any location with inorganic soil contamination is a candidate. According to the Army Environmental Requirements and Technology Assessments, 477 unique sites with confirmed inorganic soil contamination are present at 74 Army installations from nine MACOMs, while 80 unique sites with suspected inorganic soil contamination are present at 17 Army installations from four MACOMs. In addition, long-term monitoring of inorganic soil contamination was needed for 63 unique sites present at 19 Army installations from four MACOMs.

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Applicable NDCEE Task

Demonstration of RangeSafe Particle Separation and Stabilization Technology at Range 25, Fort Dix (Task N.257)

Ultrahigh-Pressure Waterjet Technology for Coatings Removal Applications

The NDCEE has extensive technical expertise with coatings removal using water-blasting technologies. A water-blasting system that can be operated either manually or with a robot has been a featured component of the NDCEE Demonstration Facility for nearly a decade. Several DoD facilities, as well as commercial industry, have used the Demonstration Facility to explore the technology's viability for their site-specific needs. Once the technology has been validated to be technically and economically beneficial for a facility, the NDCEE provides implementation and training assistance to the facility. Most recent beneficiaries of the NDCEE's coatings removal knowledge include U.S. Army Kwajalein/Regan Test Site, Schofield Barracks, Fort Eustis, and Combat Equipment Group-Afloat. Past beneficiaries include Crane Army Ammunition Activity; Naval Air Depot - Jacksonville; Naval Surface Warfare Center, Carderock Division; Norfolk Naval Shipyard; and Corpus Christi Army Depot.

DoD Need

Environmentally preferred cleaning and coatings removal technique

Service Need Numbers

Air Force: 100-123, 202, 213, 221, 298; 200-300, 304, 309, 322, 327, 332; 800-814, 900-2095, 1600-1646, 1700-1754

Army: 2.1.h, 2.3.k, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

Technology Description

Waterjet stripping uses the impact force of pressurized water to effectively remove a variety of coatings ranging from paints, rubbers, and sealants to more tenacious coatings such as aerospace adhesives and metal flame spray coatings. These coatings may be removed from many different types of substrates including metals, plastics, composites, and concrete. Due to its high versatility, waterjet stripping has applications in several industries including automotive, aerospace, shipbuilding, and construction.

Waterjet stripping involves the use of water at pressures above 10,000 psi to mechanically remove coatings. High-pressure pumps force water through specially designed nozzles that direct the high-velocity stream to impinge upon the coated substrate. The kinetic energy of the waterjet physically erodes the coating to expose the underlying substrate surface.

The waterjet can be operated under an open or closed-loop system. If the waterjet unit is a closed-loop system, it will also eliminate water discharge, reduce water consumption, and concentrate waste for less costly disposal. In a closed system, a sump pump directs the resulting water/coating mixture to a centrifugal separator that removes most of the particulate matter. The water then passes through a series of filters and tanks for further purification before reuse. The system requires only a small amount of make-up water to compensate for evaporative losses, but both recycled and make-up water must be of sufficient purity so as not to introduce sediments or other impurities that may interfere with the proper functioning of equipment.

In an investigation that was conducted on behalf of TACOM, the NDCEE determined that a manual UHPWJ system is effective at removing paint and preparing surfaces of Army tracked and wheeled vehicles. As part of its investigation, the NDCEE designed and constructed a user-friendly, portable closed-looped UHPWJ system that uses water pressures up to 36,000 psi. The system consists of a heavy nylon-shelled shelter that is 28-feet long x 24-feet wide x 17-feet high. The shelter rests within an inflatable subfloor that consists of a heavy vinyl floor and individually inflatable berms to contain process water. The system meets all National Emission Standards for Hazardous Air Pollutants, and Control Techniques Guidelines. In FY01, the shelter, with minor modifications, was transitioned to Schofield Barracks (technology isn't being used).

Removal of flame spray coating using UHPWJ

Technology Benefits and Advantages

- Eliminates hazardous airborne particulate from blasting operations, decreases solid waste by 90%, and eliminates the use of chemical strippers
- Minimizes, and in some cases eliminates, part preparation steps such as masking
- Reduces labor and operating costs as a result of increased removal rates and decreased preremoval preparation and postremoval cleanup
- Improves safety and worker health conditions due to the elimination of exposure to hazardous chemicals and decoating residues
- Is available in automated systems, both stationary and portable, that are fairly simple to operate and maintain
- Provides vacuum recovery and recycling via commercially available systems; therefore, construction or containment of the blast area is not needed when using these types of systems
- Results in "near zero" discharge
- Allows for selective stripping with system adjustment
- Helps facilities to comply with Executive Order 13148, which requires the DoD to decrease the amount of waste that is generated at federal facilities, as well as environmental regulations regarding airborne particulate emissions

Technology Limitations

- Capital costs are high. Manual systems are available for $100,000–$120,000, while some robotic systems may cost over $1 million.
- Technology has operational and maintenance training requirements.
- A separate system is needed to collect, filter, and recycle stripping water containing coating debris.
- The proper selection of blasting pressure, nozzle type, and standoff distance is critical.
- Pressures above 25,000 psi require the use of robotic equipment.

NDCEE FY03 Accomplishments

- Conducted field demonstrations on four coating removal processes on behalf of Fort Eustis and NAB Little Creek. Sponge, fiber, water, and wet sodium bicarbonate blasting were evaluated on their ability to meet the facilities' production requirements and waste reduction needs. They also were tested on some delicate substrates to determine if the substrates would be damaged during the coating removal process. Based on test results, the NDCEE recommended water or fiber media blasting for NAB Little Creek. Results were documented in a Technical Report.
- Facilitated transition of a waterjet system to the U.S. Army Kwajalein/Regan Test Site (Marshall Islands). In FY04, three field demonstrations will be conducted: 1) vacuum recovery system for the transitioned waterjet; 2) hand-held waterjet tool (with a self-contained vacuum recovery unit); and 3) a vacuum lance for coatings removal.
- Produced a Final Report on Task N.227 accomplishments. Included in this report was a discussion on the NDCEE waterjet demonstration at Naval Station Mayport. At a pressure of approximately 30,000 psi, the automated UHPWJ technology removed polyurethane coatings from SHT at an average rate of 270 square feet per hour, a noticeable improvement over the current removal rate of 12 square feet per hour. To remove nonskid coatings from a submarine steel hull, the average removal rate for open- and closed-cycle UHPWJ tools was 175 square feet per hour, which

is more than a 50-fold increase from the baseline process of abrasive blasting. UHPWJ was recommended for implementation in these applications. As part of its technology evaluation, the NDCEE also conducted a cost-benefit analysis using the ECAM℠ tool to ensure EHS issues that are associated with the coating removal process were included.

Economic Analysis

As part of its FY01 UHPWJ blasting investigation on Army tracked and wheeled vehicles, the NDCEE conducted a financial analysis with the ECAM℠ tool that compared the UHPWJ system to conventional abrasive blasting for two types of maintenance activities (HMMWV and dump truck) at both depot and field levels. Based on a 15-year study period, the ECAM℠ results revealed that it would be in the best financial interest for field-level maintenance facilities to change their current processes and each implement a UHPWJ system. The approximate annual operating cost benefit is $83,000–$110,000. The corresponding discounted payback periods are approximately 3.5 years and 5 years, respectively. The 15-year NPV is projected to be $2.3 million; the IRR is 23%.

Under another effort, a cost-benefit analysis was conducted on the use of the UHPWJ for three coatings removal applications: polyurethane from SHT, nonskid from steel, and SHT residual from steel. All three applications were combined into one cost analysis. Additionally, all options on the UHPWJ equipment were included in the initial capital costs, making the total system cost approximately $1.2 million. Several options exist for a facility to select a less expensive system depending on the application and workload. The UHPWJ showed good potential labor, materials, and maintenance cost savings, but a low NPV and IRR. The simple and discounted payback periods are 4.2 and 4.6 years, respectively.

Suggested Implementation Applications

Because of its high versatility, UHPWJ blasting has applications in several industries, including automotive, aerospace, shipbuilding, and construction. As a cleaning process, water blasting is efficient at removing oil and grease from parts with simple geometries and removing particulates from parts with complex geometries to precise cleanliness levels. Applicable weapon system components include ship and aircraft radomes, SHT tiles on submarines, and fiberglass hoods on HMMWVs.

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Applicable NDCEE Tasks

Pollution Prevention Initiative (Task N.227, Mod 1)

Sustainable Green Manufacturing (Task N.301, Subtask R3-10)

U.S. Army Kwajalein/Regan Test Site Corrosion Control & Removal (Task N.305)

Unexploded Ordnance Neutralization Technologies

With assistance from DoD unexploded ordnance (UXO) stakeholder teams, the NDCEE is providing technical expertise that is specific to the UXO challenges faced by the DoD. Topics that are under investigation include: UXO neutralization and remediation technologies, quality control procedures for UXO technology operators, land use controls as a UXO response, UXO migration, and active electromagnetic induction effects on electronic fuzes. In addition, the NDCEE redesigned and populated a Web-accessible database for UXO recovery and removal actions.

Technology Description

UXO neutralization technologies neutralize UXO either by preventing it from functioning or by intentionally disrupting its normal operation. Per its Statement of Work, the NDCEE only considered a subset of all technologies that are encompassed by this definition. The technologies of interest were those that are permanently eliminating the ability of conventional UXO items' energetics to explode, with or without complete destruction of the case. Open burn and open detonation methods were included, but render-safe practices, such as defusing or disrupting normal functioning, were excluded.

The DoD is interested in neutralization technologies that offer improvements in cost, operator safety, and environmental impact in comparison to traditional methods such as open burning and open detonation using flares or C4 and involving close proximity of personnel with the UXO. The NDCEE has identified several emerging technologies that may meet the DoD's needs. For most, initial research and development work has been completed, with at least a prototype available for possible demonstration and validation work. However, little to no commercialization has occurred in the UXO arena.

DoD Need

UXO-free operational and former ranges

Service Need Numbers

Army: 1.6.b

Navy: 1.I.04.e

Based on stakeholder recommendations, the NDCEE narrowed its investigation to five technologies:

- Joint Laser Ordnance Neutralization System (J-LONS): a system that uses laser energy to neutralize UXO targets.
- Light Energy Absorbing Igniter (LEAI): a nonexplosive reusable system that neutralizes UXO targets by applying light energy to initiate a burn or a detonation from a distance.
- Telepresent Rapid Aiming Platform (TRAP): a fully mature system in use by the DoD and police in sniper operations and hostage situations. Designed to support a variety of tactical weapons (up to .50 caliber), it can be aimed and fired from a remote location via a handheld controller directly at UXO items, causing primary detonation and neutralization of the UXO item.
- The Mine Incinerator®: a low-order neutralization technology that usually consumes the main explosive charge of amine or UXO without detonation, avoiding the potential for damage, hazard, or shrapnel dispersion that is normally associated with blow-in-place practices.
- Fiber Optics Delivered Energy System: a diode laser device (self-contained on a John Deere Gator all-terrain vehicle with trailer) that neutralizes non-line-of-sight UXO via fiber-optics delivery of the laser energy.

Technology Benefits and Advantages

J-LONS

- Effective in dealing with UXO on the surface where it is accessible by direct line-of-sight
- Good standoff capability, resulting in minimal health and safety risks to personnel

LEAI

- Portable
- Direct line-of-sight required only from the transmitter to the receiver/controller unit, not from the safe area to the UXO site
- Quicker, safer disposal operations that require fewer labor hours than the current method of firing leads or shock tubes

TRAP

- Mature technology that is in full production
- Reliability factor of greater than 95% and an aim resolution of 0.1 minute of angle
- Multiple safety systems to prevent accidental firing of the weapon (the probability of inadvertent discharge is reported as being less than 10^{-6})
- Good standoff capability, resulting in minimal health and safety risks to personnel

The Mine Incinerator®

- Useful for most exposed conventional UXO
- Field tested in Kosovo, where most tests resulted in an effective 90% reduction in the danger zone as compared to high-order detonation, reducing the collateral damage to the surrounding infrastructure
- Environmentally benign solid, nonmagnetic reaction products
- Stored safely in large quantities for an indefinite period of time
- Chemically inert and moisture insensitive; should be handled as any other solid flammable material

Fiber Optics Delivered Energy System

- Useful in terrestrial areas with blow-in-place applicability
- Does not require direct line-of-sight between unit/operator and UXO
- Lower potential for eye damage with fiber optics in comparison to direct laser systems

Technology Limitations

All of the following technologies require the UXO to be at or above the ground surface.

J-LONS

- Not useful when the UXO is concealed by intervening structures, topography, vegetation, etc. Consideration is being given to including a fiber optic component, which would give the system a subsurface and an around-obstruction capability.

LEAI

- Cannot be used in dense foliage where the transmitter-to-receiver/controller unit view is obstructed
- Cannot be used to split open a large piece of ordnance
- Requires personnel to be in direct contact with the UXO during positioning of flares and ignitor

TRAP

- Not suited for buried UXO, areas that cannot be safely excavated, or areas without direct line-of-sight from the weapon to the UXO
- Down-range hazard due to high-velocity projectile
- Production of ground contamination is associated with the detonation

The Mine Incinerator®

- Requires personnel to be in direct contact with the UXO during positioning of the system
- Dutch-owned system that has been unavailable due to shipping problems that are associated with the events of September 11, 2001

Fiber Optics Delivered Energy System

- Issues with fiber tip damage during operation have prevented consistent successful neutralization events during a recent demonstration

NDCEE FY03 Accomplishments

- Assembled a team of UXO stakeholders, including representatives from U.S. Army Corps of Engineers, U.S. Army Environmental Center, Joint UXO Coordination Office, Air Force Research Laboratory, Naval Explosive Ordnance Disposal Technology Division, Interstate Technology Regulatory Council, and National Association of Ordnance and Explosive Waste Contractors.
- Performed an in-depth literature search to consolidate information on UXO neutralization technologies and identified data gaps in those technologies. Eleven technologies were identified as potentially offering safety and cost-effective advantages to the Government over current practices. Five of those technologies were selected for further investigation based on stakeholder preferences. Findings were described in the UXO Neutralization Technology Technical Report.

Economic Analysis

Depending on the UXO neutralization technology, capital investment can range from $20 per unit to several thousand dollars. Although capital costs allow a direct comparison to be made among the various technologies, they do not allow the most important costs to be compared (i.e., the costs to remediate contaminated land). The reason is due to the fact that some of the technologies lead to burning of the UXO item, some to low-order detonation, and some to high-order detonation. Therefore, land remediation requirements following neutralization may vary significantly from one technology to the next.

Soil contamination is a function of neutralization methods. Subsequent remediation will be needed based on site-specific criteria as well as the chosen neutralization method. For example, a low-order detonation technology with a low cost per shot may result in higher total costs than a high-order detonation technology with a higher cost per shot. Therefore, a true comparison of neutralization technologies can only be performed by considering all aspects that are involved in the neutralization process (i.e., including all steps immediately following detection through complete site remediation). At this time, a full-costing methodology for UXO neutralization, including land remediation costs subsequent to ordnance neutralization, has not been developed.

Suggested Implementation Applications

As of the end of FY02, the DoD had identified 2,307 sites where UXO remediation should be considered. These sites include operational ranges, Formerly Used Defense Sites (FUDS), Base Realignment and Closure (BRAC) installations, and closed ranges on active bases.

Points of Contact

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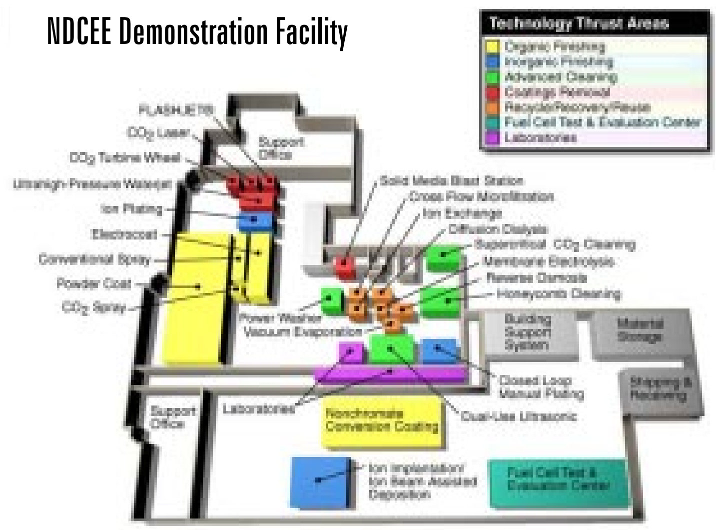
Applicable NDCEE Task

Unexploded Ordnance (UXO) (Task N.307, Subtask 2)

TECHNOLOGY DEMONSTRATION FACILITY EQUIPMENT

NDCEE Demonstration Facility



NDCEE

the missing piece to today's environmental solutions

NDCEE Technology Demonstration Facility

Located in Johnstown, Pennsylvania, the NDCEE Demonstration Facility is a venue for independent, third-party verification of environmentally beneficial technologies. In this real-life production environment, clients can try-out, validate, and receive hands-on, in-depth training on new environmentally acceptable processes and materials before implementing them in their own facilities.

By using the Demonstration Facility, clients can reduce many of the technical and financial risks that are associated with implementing a new technology. For instance, DoD installations can select the best alternative by evaluating several state-of-the-art technologies in proof-of-principle demonstrations at the facility instead of shutting down their own production lines. Hardware and software can be tested before investments are made throughout the DoD. Client personnel can evaluate alternatives according to projected performance and cost factors, including equipment costs, start-up costs, throughput rates, operating costs, and product quality. Alternatives may be commercially available technologies or custom-designed prototypes.

Once an alternative is selected, DoD personnel can use the facility to conduct a full-scale process validation under realistic operating conditions. In this way, the technology is evaluated against client standards to ensure that technical; production; environment, health, and safety; and cost requirements are satisfied. All testing is performed in accordance with approved test plans.

The Demonstration Facility is built based on an understanding of end-user needs. It is designed to provide flexibility, modularity, and consideration of human factors. It integrates pollution prevention concepts to provide a fully self-contained operation. The facility includes quality control and device calibration laboratories, warehousing and maintenance areas, worker facilities, and a complete utility infrastructure.

The Demonstration Facility currently houses approximately 20 commercial-scale production technologies in the areas of cleaning; stripping; vacuum coating; organic and inorganic finishing; recycle, recovery and reuse; and electroplating. To ensure that these technologies remain state-of-the-art, the NDCEE keeps abreast of improvements in the technologies and provides recommendations to the Government for upgrades. These recommendations are based on existing knowledge and experience working with the DoD and industry and take into account the DoD's highest-priority environmental needs.

The following section contains a summary of each technology that is located in the Demonstration Facility. In addition to providing recommended upgrades based on current industry standards and DoD needs, each summary provides an overview of the technology, its specifications, its benefits and advantages, its limitations and disadvantages, representative NDCEE tasks, and potential technology transfer applications. The current value of each technology also has been calculated based on a straightline depreciation method as referenced by Internal Revenue Service regulation 1.167. This information is provided to aid in determining whether or not upgrades to the technology are justified.

Lastly, each technology has been aligned with applicable high-priority needs. The need codes were obtained from each Service's requirements report, as cited in the reference section of this document.

Closed-Loop Manual Plating Line

(Electroplating)

Overview

Environmental compliance costs are driving the metal plating industry to search for ways to reduce the volume and toxicity of its waste through "greener" plating processes and materials. The closed-loop electroplating line that is located in the NDCEE Demonstration Facility reduces the volume of wastes that is associated with electroplating operations through source reduction, recycling, and resource recovery. Counter-current rinsing and recovery technologies reduce wastewater from rinsing operations and their resulting RCRA-classified F006 sludges.

The line, which is capable of operating under any condition that is necessary for general electroplating and electroless plating, is used to evaluate new electroplating processes, particularly those that use noncyanide process chemicals and replacement metals for hexavalent chromium and cadmium. Typical processes that are available for demonstration include noncyanide copper, acid and alkaline zinc nickel, electroless nickel, electroless nickel-boron, nickel-tungsten-silicon-carbide, nickel-tungsten-boron, and noncyanide silver. Each of these processes is evaluated for its engineering properties, environmental advantages, life-cycle cost, and production readiness. The line can also be used to evaluate other new alternatives as they become available.

The NDCEE Closed-Loop Manual Plating Line is easily configurable to any special requirement of the user. Designed for rack and barrel processing, the line processes parts up to 2' x 2' x 1' in size and weighing up to 250 lbs. Electrocleaning and acid activation prepare the parts for plating. Four in-line plating stations can handle any type of plating solution. Each plating tank is separately bussed, filtered, and heated. Temperature is automatically controlled at ±5°F. Each tank is equipped with both air and mechanical agitation. Fumes are exhausted from each tank through a packed bed scrubber with a mist eliminator prior to discharge. All scrubber water is also recycled.

The line is designed for near-zero water discharge. Multiple rinsing sequences (spray rinsing, double or triple counter flow, or a combination of these sequences) minimize wastewater that requires treatment or disposal. All rinses are segregated and undergo a recycling process, such as microfiltration, reverse osmosis, or evaporation, depending on the specific electroplating process.

Specifications

The following table contains the specifications and parameters of the NDCEE Closed-Loop Manual Plating Line.

Closed-Loop Manual Plating Line Specifications and Operating Parameters

Specification	Parameter
Maximum Part Size	2' x 2' x 1'
Maximum Part Weight	250 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Closed-Loop Manual Plating Line.

Original Purchase Cost and Current Value of the Closed-Loop Manual Plating Line

Purchase Cost	Current Value	Years of Service
$190,400	$63,467	8

Technology Benefits and Advantages

- High-quality parts can be obtained without generating wastes.
- Hardness, lubricity, fatigue, and corrosion resistance of the coating can be optimized by varying bath operating parameters such as time, temperature, current density, and solution concentration.
- The equipment is reconfigurable to demonstrate a variety of processes.
- The equipment reduces the volume of wastes that are associated with electroplating through source reduction, recycling, and resource recovery.
- Counter-current rinsing and recovery systems in a closed-loop plating line reduce wastewater from rinsing operations.
- The process is beneficial to the environment by reducing hazardous waste.

Technology Limitations and Disadvantages

- Part sizes that can be processed are limited by the size of the plating tanks.

Recommended Upgrades for Continued DoD Support

The plating line currently meets or exceeds modern industry standards and is maintained in operational condition. Currently, no upgrades to the system are recommended.

Representative NDCEE Tasks

Environmental Metal Plating Alternatives - Electroless Nickel Plating Rejuvenation (Task N.089)

- Evaluated technologies that are capable of reducing the amount of waste that is generated by electroless nickel plating processes

Evaluation of Noncyanide Silver Plating (Task N.104)

- Evaluated commercially available noncyanide alternatives to silver plating processes

Materials and Process Partnership for Pollution Prevention/Pollution Prevention Initiative (Task N.227)

- Evaluated commercially available noncyanide alternatives to copper and silver plating processes

Alloy Plating to Replace Cadmium on High-Strength Steels (Task N.000-02, Subtask 7)

- Evaluated commercially available noncyanide alternatives to cadmium plating processes

Sustainable Green Manufacturing (Task N.301, Subtask R4-1)

- Evaluated commercially available noncyanide alternatives to cadmium plating processes

Potential Technology Transfer Applications

This technology could be applied in those applications that are looking to reduce waste and/or identify environmentally friendly alternatives through electroplating and electroless plating.

DoD Need

Environmentally compliant surface protection and corrosion control

Service Need Numbers

Army: 2.1.g

Navy: 2.I.01.g, 2.I.01.q, 3.I.03.b, 3.I.03.e, 3.I.11.b, 3.I.13.a

Closed-Loop Manual Plating Line

CO_2 Turbine Wheel (Blasting) Technology

Overview

Carbon dioxide blasting is a cleaning and stripping process whereby solid CO_2 pellets (dry ice) is propelled by a stream of compressed air and directed at the surface that is to be treated. The high speed of these pellets can knock loose any contamination, strip a coating, or etch a surface. However, unlike abrasive blasting media, the pellets do not abrade metallic substrates. Both pneumatic and turbine wheel CO_2 pellet blasting systems are available. A turbine wheel system is housed in the NDCEE Demonstration Facility.

The turbine wheel system uses a high-speed centrifugally accelerated turbine wheel to shoot pellets of solid CO_2 onto a surface. As the dry ice pellets strike the surface, they induce an extreme difference in temperature (thermal shock) between the coating or contaminant and the underlying substrate, weakening the chemical and physical bonds between the surface materials and the substrate. In addition, mechanical impact or abrasion occurs. Immediately after impact, the pellets begin to sublimate (vaporize directly from the solid phase to a gaseous phase), releasing CO_2 gas at a very high velocity along the surface that is to be cleaned. This high velocity is caused by the extreme density difference between the gas and solid phases. The kinetic energy that is produced dislodges the contaminants (coating systems, contaminants, flash, etc.), resulting in a clean surface.

Waste cleanup and disposal are minimized because only the coating or contaminant residue remains after blasting. No liquid waste is generated because CO_2 pellets disintegrate. They pass from a solid to a gaseous state, leaving no spent media residue. With regard to toxic air control, small quantities of coating particles are emitted to the air. A standard air filtration system should be provided.

DoD Need

Environmentally compliant coatings removal technique

Service Need Numbers

Air Force: 100-202, 213, 221, 298; 200-304, 309, 322, 327, 332; 900-2095; 1600-1646; 1700-1754

Army: 2.1.h, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

The equipment and materials that are needed for this technology include a source of liquid CO_2, a pelletizer, and alternate current power. The uniformed pellets are produced in the CO_2 pelletizer, which uses liquid CO_2 as its source. Variables that affect process optimization include the following: pellet density, mass flow, pellet velocity, and propellant stream temperature.

CO_2 pellet blasting is effective for cleaning, degreasing, some depainting, and deflashing (flashing is the excess material formed on the edges of molded parts) applications. It also provides excellent surface preparation prior to application of coatings or adhesives and is suitable for most metals and some composite materials. However, thin materials may be adversely affected. Blasting efficiency is approximately equal to that of other blasting operations and can approach 1 ft^2/minute after optimization.

Specifications

The following table contains the specifications and parameters for the NDCEE CO_2 Turbine Wheel.

CO_2 Turbine Wheel Specifications and Operating Parameters

Specification	Parameter
Pelletizer	Alpheus Model 290
Pellet Blaster	Alpheus Model 45
Rotary Pellet Blaster	Cryogenics Applications F, Inc.
Rotary Blaster Robot	Fanuc 420 Robot
CO_2 Capacity	300–600 lbs. of 1/16" x 1/16" D pellets per hour

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE CO_2 Turbine Wheel.

Original Purchase Cost and Current Value of the CO_2 Turbine Wheel

Equipment	Purchase Cost	Current Value	Years of Service
Pelletizer, Pellet Blaster, and Rotary Pellet Blaster	$117,000	$39,000	8
Rotary Blaster Robot	Loaned by the Air Force	Not Applicable	8

Technology Benefits and Advantages

- Significantly reduces the amount of hazardous waste and hazardous air emissions that are generated compared to chemical stripping
- Reduces time required for cleaning/stripping processes by 80%–90%
- Leaves no residue on the component surface
- Is effective in precision cleaning
- Does not introduce any new contaminants
- Does not add to the volume of waste that is generated because the residual CO_2 media evaporates

Technology Limitations and Disadvantages

- CO_2 blasting is not always a one-pass operation; an effective blasting operation usually requires multiple passes to achieve the desired effect.
- Operator training is required.
- CO_2 blasting can have high capital costs.
- Fixed-position blasting operations can damage the component's surface.
- Rebounding pellets may contain coating debris and contaminate work area. Some soils (in cleaning operations) may redeposit on substrate.
- Nonautomated system fatigues workers quickly because of cold temperature, weight, and thrust of blast nozzle. Automation (robotics) is required for full aircraft stripping operations.
- A potential hazard exists from using compressed air or high-velocity CO_2 pellets. The process shows the potential to cause peening and warping on thin materials such as sheet aluminum less than 0.060" thick.
- Equipment noise levels are high (95–130 dB); hearing protection is required.

Recommended Upgrades for Continued DoD Support

Currently, no upgrades for the NDCEE equipment are recommended.

CO_2 Pellet Blasting Operations System

Representative NDCEE Task

Mobile Manipulation of a Carbon Dioxide Pellet Turbine Wheel (Task N.045)

- Evaluated the CO_2 pellet removal system on electrocoat, powder coat, chemical agent resistant coating, and nonskid coated surfaces
- Incorporated a flexible workcell design for use on a variety of parts

Potential Technology Transfer Applications

This technology is effective for removing oils and dust from hazardous shipping containers. In addition, it is effective in removing some paints, sealants, carbon and corrosion deposits, grease, oil, and adhesives as well as solder and flux from printed circuit board assemblies.

Cross-Flow Microfiltration Units
(Kinetico Microfiltration Mobile Unit and Kinetico Bench-Scale Unit)

Overview
Microfiltration is a recycle/recovery technology that is generally used to remove solid particulate or emulsified contaminants from process solutions such as alkaline cleaning baths and electroplating/stripping bath rinses. Microfiltration can also be used to remove microorganism contamination from process solutions.

Microfiltration technology operates by use of a membrane system in which the membrane material and pore size can be varied depending on the application. Pore sizes for microfiltration membranes range from 0.1–5 microns. Smaller pore-sized membranes, utilized in ultrafiltration techniques, range from 0.005–0.1 micron.

Cross-flow microfiltration is a filtration process in which the process fluid is passed through a filter membrane under pressure. The pressure of the passing fluid forces process fluid through the membrane pores, with the solid and emulsified materials remaining on the process side of the membrane. The fluid that is forced through the membrane is known as the permeate solution and is circulated to a holding tank. The remaining process solution with the solid contamination is circulated back to the process tank for additional passes through the filter membrane until the solids in the process fluid cause the pressure of the microfiltration system to climb and the process flow to drop considerably. At this point, the remaining solution is known as the concentrate.

The NDCEE Demonstration Facility contains both a full-scale and a bench-scale cross-flow microfiltration unit.

Specifications
The following table contains the specifications and parameters for the NDCEE Cross-Flow Microfiltration Units.

Cross-Flow Microfiltration Specifications and Operating Parameters

Specification	Parameter
Flow Rate	Full-scale unit - 5 gpm Bench-scale unit - 0.5 gpm
Filter Porosity	0.005–0.8 microns
Pressure	65 psi
Membrane Material	Ceramics, teflon, polypropylene, and other plastics
Material of Construction	PVC

Current Equipment Value
The following table contains the purchase cost and current equipment value of the NDCEE Cross-Flow Microfiltration Units.

Original Purchase Cost and Current Value of the Cross-Flow Microfiltration Units

Purchase Cost	Current Value	Years of Service
$250,000	$104,167	7 (for each unit)

Technology Benefits and Advantages

- Demonstrates wide array of process solutions
- Helps to meet compliance with pretreatment standards for discharge regulations
- Helps to meet effluent limits of NPDES permit
- Reduces waste volume by purifying and recycling contaminated water
- Reduces hazardous waste

Technology Limitations and Disadvantages

- Membranes can be costly and time consuming to clean, depending on the solution to be recovered.

Recommended Upgrades for Continued DoD Support

Currently no upgrades for the NDCEE units are recommended.

Representative NDCEE Tasks

Red River Army Depot Microfiltration Evaluation of Zinc Phosphate Solution (Task N.108)

- Evaluated microfiltration as an alternative technology to prolong the life of pretreatment baths
- Completed a cost analysis and an environmental impact comparison in relation to current processes

NDCEE Demonstration Projects - Alternative Cleaning Solution Recycle/Recovery (Task N.000-01, Subtask 5)

- Conducted bench-scale trials to recycle rust remover solutions

Potential Technology Transfer Applications

This technology could be applied in those applications that require the removal of solid particulate or emulsified contaminants from various types of process solutions.

DoD Need

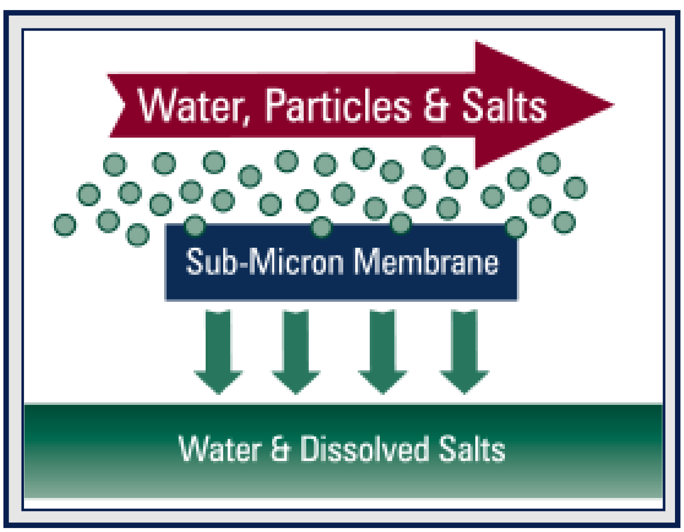
Improved treatment of effluent discharges

Service Need Numbers

Air Force: 600-643, 1200-1276

Army: 2.2.a, 2.2.e, 2.2.f

Navy: 2.II.01.q, 3.I.03.b, 3.I.11.b, 3.I.11.j, 3.I.13.a, 3.III.06.d



Microfiltration Process

Diffusion Dialysis Unit

(Kinetico Diffusion Dialysis Mobile Unit)

Overview

Diffusion dialysis techniques are generally used to remove metals contamination from concentrated acid solutions. Common uses include recycling plating or stripping baths that are composed of sulfuric, nitric, phosphoric, or hydrochloric acids, or combinations of these acids and weak acids. A variety of metals can be removed or recovered, depending on the value of the metal. Some types of metals include zinc, iron, copper, chromium, nickel, and silver.

Diffusion dialysis functions by passing process fluid through a stack of semipermeable membranes. The unit that is housed in the NDCEE Demonstration Facility utilizes an anion permeable membrane, where the acid anions pass through the membrane to the low concentration, deionized water side of the membrane. The metals remain trapped on the high concentration side of the membrane, which contains the original process solution. The result of this process is an 80–95% recovery of the initial acid solution (somewhat diluted with deionized water) and 60–95% recovery of the metals.

Specifications

The following table contains the specifications and parameters of the NDCEE Diffusion Dialysis Unit.

Diffusion Dialysis Unit Specifications and Operating Parameters

Specification	Parameter
Stack Size	2 liters/hour or 5 liters/hour
Membrane	Anion permeable

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Diffusion Dialysis Unit.

Original Purchase Cost and Current Value of the Diffusion Dialysis Unit

Purchase Cost	Current Value	Years of Service
Est. at $200,000	$83,333	7

Technology Benefits and Advantages

- Reduced hazardous waste volume and the associated disposal costs
- Metals reclamation and reduction of liability if sludge is recovered by an outside company
- Lower annual cost for chemical makeup and replacement
- Improved production quality and consistent reproducibility of manufactured parts due to control of the metal ion concentration in the anodizing bath solution
- Beneficial to the environment by reducing hazardous waste
- More cost-effective than conventional treatment and discharge
- Application-specific size feature

Technology Limitations and Disadvantages

- Moderately high capital cost
- Increase in the number of possible exposures with regard to the handling of hazardous waste

Recommended Upgrades for Continued DoD Support

The NDCEE Diffusion Dialysis Unit currently meets or exceeds modern industry standards. The equipment is maintained in operational condition or in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the system are required at this time.

Representative NDCEE Task

Evaluation of Adsorption Technology to Recover Contaminated Mineral Acid Solutions (Task N.064)

- Recovered mineral acid from iron contaminated hydrochloric acid solution

Potential Technology Transfer Applications

This technology could be applied in those applications that are looking to recover mineral acids from spent plating solutions and other concentrated acid stripping operations.

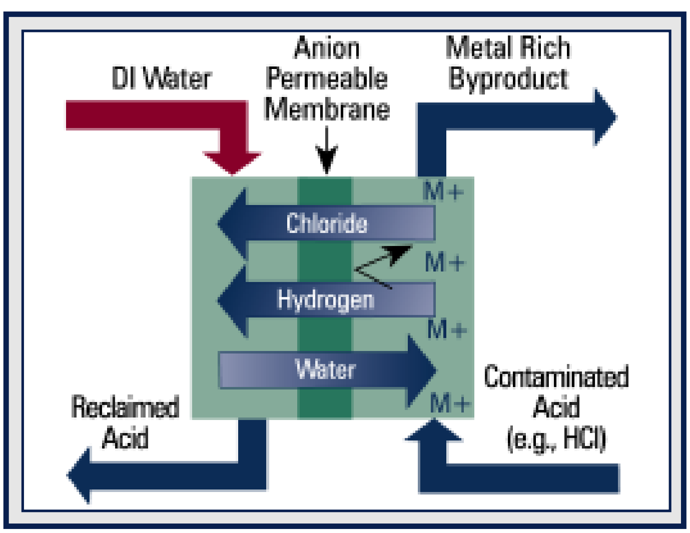
DoD Need

Improved treatment of effluent discharges

Service Need Numbers

Army: 2.2.f

Navy: 2.II.01.q, 2.III.01.b, 3.I.03.b, 3.I.11.b, 3.I.13.a



Diffusion Dialysis Process

Dual-Use Ultrasonic System

Overview

The Dual-Use Ultrasonic System uses aqueous/semiaqueous solutions to clean and degrease a wide variety of parts. The system is comprised of five stainless steel tanks and a dryer. The stages include a wash station, emulsion rinse tank, three cascading water stages, and a "hot-air" dryer. The emulsion rinse, which may also be used for aqueous washing, and first water rinse tanks use ultrasonic and mechanical spray-under-immersion agitation to clean parts. Wash and rinse solutions can be recycled after filtration and oil clarification. Parts are rinsed in fresh or deionized water. Compressed air removes moisture from the parts before they are dried in the drying chamber.

Specifications

The following table contains the specifications and parameters of the NDCEE Dual-Use Ultrasonic System.

Dual-Use Ultrasonic System Specifications and Operating Parameters

Specification	Parameter
Washing Temperature	80–180ºF
Rinse Temperature	80–180ºF
Dryoff Temperature	300ºF
Maximum Part Size	3' x 4' x 4'
Maximum Part Weight	250 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Dual-Use Ultrasonic System.

Original Purchase Cost and Current Value of the Dual-Use Ultrasonic System

Purchase Cost	Current Value	Years of Service
$506,000	$168,667	8

Technology Benefits and Advantages

- May be set at various temperatures, pressures, cycle times, and ultrasonic frequency settings for optimum performance
- Attains very high levels of cleanliness
- Removes small particles from small through-holes
- Removes debris from parts with complex geometries
- Decreases cleaning times over traditional immersion cleaning without ultrasonics

Technology Limitations and Disadvantages

- Not as effective as directed sprays for cleaning blind holes

Recommended Upgrades for Continued DoD Support

The NDCEE system presently meets or exceeds industry standards. The equipment is maintained in operational condition. Currently, no upgrades to the system are recommended.

Representative NDCEE Task

Nonhalogenated Systems for Cleaning Metal Parts (Task N.007)

- Identified, tested, and evaluated environmentally compliant, technically and economically feasible nonhalogenated metal parts cleaning system

Potential Technology Transfer Applications

This technology could be applied in those applications that are looking to have large-scale contaminated surface areas cleaned with aqueous/semiaqueous solutions.

DoD Need

Environmentally compliant cleaning methods

Service Need Numbers

Army: 2.1.h, 3.2.j

Navy: 2.I.01.g, 2.I.01.q, 2.I.01.s, 3.I.11.b, 3.I.13.a

Dual-Use Ultrasonic System

Electrocoating Line

Overview

Electrocoating (E-coat) is an electrodeposition process that applies specially formulated organic coatings to conductive substrates by means of an aqueous paint bath. It provides the substrate with exceptional corrosion protection and weatherability because of its ability to completely and uniformly coat all surfaces and deep recesses of complex-shaped parts. This capability allows the automotive, appliance, utility, and other high-volume industries to use E-coat extensively for precision application of primers and one-coat enamels. Coatings are applied to a wide variety of products, including agricultural equipment, furniture, automotive parts, wheels, electric transformers and switchgears, washing machines and dryers, microwave oven cavities, heating and cooling systems, and metal cans.

E-coat is environmentally friendly because it uses waterborne paints. Coatings contain 85–95% nonvolatile solids, excluding water. In addition, the E-coat Line in the NDCEE Demonstration Facility eliminates solid wastes by recycling process materials through closed-loop rinsing and ultrafiltration.

The E-coat process can coat up to 2,500 square feet of metal per hour. Its 95% minimum transfer efficiency and automated process cycles result in significant cost savings and productivity gains. Labor and material usages are reduced as well.

Parts that are to be electrocoated first pass through a cleaning/pretreatment subsystem to remove dirts, oils, and drawing compounds. Depending on the application, either iron or zinc phosphate pretreatments can be applied for adhesion and/or corrosion protection, respectively. After pretreating and drying, parts enter the E-coat Line via an overhead conveyor and are lowered in and out of process tanks by indexing lifts.

The five-stage coating process begins with dip application of the coating in the main paint bath, or tank. Once coated, excess coating is removed by a series of rinses: a spray rinse, an immersion rinse, a second immersion rinse, and a final spray rinse with deionized water. Rinse waters are counterflowed and pass through a closed-loop, pressure-induced ultrafiltration system that separates the paint solids from the rinse water. The rinse water is then recycled into the main E-coat tank. This process conserves material, decontaminates the bath, and controls the paint performance. Parts are then conveyed to a thermal curing oven for curing.

Specifications

The following table contains the specifications and parameters of the NDCEE E-Coat Line.

E-Coat Line Specifications and Operating Parameters

Specification	Parameter
Number of Stages	5
Capacity	2,500 ft^2/hr
Loads per Hour	1 to 20
Maximum Part Size	4' x 4' x 3'
Maximum Part Weight	250 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE E-Coat Line.

Original Purchase Cost and Current Value of the E-Coat Line

Purchase Cost	Current Value	Years of Service
$625,000	$208,333	8

Technology Benefits and Advantages

- Reduces environmental impacts that are associated with hazardous solvents and solid/hazardous waste generation and disposal over conventionally spray applied primers
- Applies a uniform coating of predetermined thickness over parts with simple or complex geometries, including sharp edges and points
- Eliminates runs and sags that are common with conventional dip or spray applications
- Can be used as an epoxy primer for most liquid or powder topcoats
- Offers many desirable coating characteristics such as abrasion and corrosion protection

DoD Need

Environmentally compliant coating system

Service Need Numbers

Army: 2.1.h, 3.2.j

Navy: 2.I.01.g, 3.I.04.e

Technology Limitations and Disadvantages

- The process is limited to one-coat application.
- Different colors require different processing tanks.
- Ventilation, after curing, is required until coated parts cool to 150°F.
- The part and conveyor carrier must be isolated from electrical ground.
- A chiller is required to maintain coating process bath temperature.
- The electrocoat tank requires daily checks by a trained chemist.
- Continuous maintenance is required for ultrafiltration system.
- Deionized water with an ultraviolet water disinfection treatment system is required to maintain bath integrity.
- Anolyte wastewater is generated as a waste stream.
- The periodic flushing of ultra filters will generate a sludge waste stream.

Recommended Upgrades for Continued DoD Support

Currently, no upgrades to the NDCEE E-Coat Line are recommended.

E-Coat Line with Multiple Components Being Rinsed

Representative NDCEE Tasks

Unitized Coating Application Facility Electrocoat and Powder Coat (Tasks N.002, N.006, and N.046)

- Evaluated reduced VOC and HAP coating systems
- Performed a life-cycle cost evaluation for two facilities

Potential Technology Transfer Applications

The E-coat process equipment would be a candidate technology to be transitioned/implemented at any DoD facility that is currently focusing on implementing VOC-compliant coatings and reducing waste streams that are associated with the maintenance of ground vehicle components, aerospace components, and a variety of composites.

Fuel Cell

Overview

The generation of electricity is typically performed through the burning of fossil fuels in internal combustion engines (i.e., gasoline, diesel, or gas turbine) or in boilers to generate high-pressure steam that is supplied to a steam turbine. A fuel cell generates electricity through an electrochemical process that is similar to a battery. However, with a fuel cell, as long as fuel is supplied, electricity is continually produced.

The principles behind fuel cells have been known since 1839, but were not practically applied until the NASA Gemini program in the 1960s. With improvements in the technology and increasingly strict pollutant emissions regulations, fuel cells are currently an economical solution in some applications. The market for applications requiring electricity is extremely large and diverse, resulting in a heightened interest and development of fuel cells for applications ranging from mobile phones to vehicular power to utility power plants. Fuel cells are expected to become commonplace during the next decade.

Fuel cells are generally more efficient in generating electricity than traditional methods. Unlike most traditional generating methods, they are scalable, meaning that the efficiency does not significantly change with size and power that is produced.

Several types of fuel cells are being developed for applications as small as a mobile phone (<1 Watt) to as large as a small power plant for an industrial facility or a small town (>10 Megawatts). The fuel cell that is being tested by the NDCEE for the U.S. Army Engineer Research and Development Center (ERDC)/Construction Engineering Research Laboratory (CERL) is a PC25C, 200 kW phosphoric acid fuel cell manufactured by UTC Fuel Cells.

The PC25C is one of the first commercially available fuel cells in this size range. The ERDC/CERL supported the installation of 30 PC25Cs at military installations around the country to gain working experience with this new technology. Under the direction of ERDC/CERL, the NDCEE established a national capability, the Fuel Cell Test & Evaluation Center (FC*Tec*) for performing comprehensive, independent testing of fuel cell power plants. The PC25C that is shown below is located in the FC*Tec* site at the NDCEE Demonstration Facility.

Specifications

The following table contains the specifications and parameters for the NDCEE PC25C Fuel Cell.

PC25C Fuel Cell Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	-20–110ºF
Electrical Power Output	0–200 kWe
Thermal Power Output	>800,000 BTUs/hr
Fuel Cell Size	212" x 114" x 121"
Fuel Cell Weight	40,000 lbs.

Current Equipment Value

The following table contains the purchase costs and current equipment value of the NDCEE PC25C Fuel Cell.

Original Purchase and Installation Costs and Current Value of the PC25C Fuel Cell

Purchase Cost	Current Value	Years of Service
$800,000	$533,333	4

Technology Benefits and Advantages

- Use of alternative or renewable energy sources helps facilities to comply with the U.S. Energy Policy Act of 1992 and other federal, state, and military directives
- Improves energy conservation and reduces environmental impacts in comparison to traditional energy sources
- High-energy conversion efficiency, fuel flexibility, and cogeneration capability
- Modular design with no moving parts
- Very low chemical and acoustical pollution
- Rapid load response
- Simple installation, no specialized fuel cell experience needed

Technology Limitations and Disadvantages

- Initial equipment costs may be high, but are improving as the technology becomes more widely disseminated.
- As with any new and advanced power technology, fuel cells involve design and construction planning as well as additional maintenance training.
- Distributed power sources require dedicated onsite space requirements.
- Caution must be exercised since high voltages are a potential danger.

Recommended Upgrades for Continued DoD Support

The NDCEE residential fuel cell system within the FC*Tec* has limited functionality and remaining life. It could be replaced with a new system to provide grid independent and or multi-fuel capabilities.

Representative NDCEE Tasks

ESTCP Validation Tasks (Task N.098)

- Investigated the uses of fuel cells in DoD applications
- Identified fuel cell applications that are not currently pursued by the DoD, including premium power, DC power, and hydrogen source applications
- Reviewed the economics of fuel cell technology including cost comparisons to more conventional energy sources

U.S. Army ERDC/CERL Fuel Cell Technology Program (Task N.211)

- Provided testing and evaluations, in cooperation with various fuel cell manufacturer's power plants, with the focus to support life-cycle cost reduction and performance improvement goals
- Provided the capability for independent design assessments of alternative technology fuel cell system configurations and components

Potential Technology Transfer Applications

Fuel cells are candidate technologies for any DoD facility that needs highly reliable, nearly emissions-free electrical power. They could substitute for older technologies, such as batteries, as an uninterruptible power supply. Collocation of electrical power needs and thermal needs (e.g., hot water or low-pressure steam) will make any installation more economical. Additional applications include remote power production in which the fuel cell is the primary energy provider, not connected to the power grid.

DoD Need

Use of alternative or renewable energy sources

Service Need Numbers

Army: 2.1.g

Navy: 2.I.01.b, 2.I.01.i

UTC Fuel Cells PC25C, 200 kW Phosphoric Acid Fuel Cell

Honeycomb Cleaning System

Overview

The Honeycomb Cleaning System was originally developed to clean aircraft honeycomb, but is suitable for difficult-to-clean parts that have strict cleaning requirements. Parts are positioned on a cart that is rolled along a track into the washer. A 385-nozzle spray bar moves back and forth beneath the parts, spraying a heated wash solution that is followed by a deionized water rinse. Overhead nozzles wash and rinse the top portion of the honeycomb. Wash and rinse solutions are then filtered and recycled. Compressed air removes excess water from the parts before they are dried by a high-capacity blower in a humidity-controlled oven.

Specifications

The following table contains the specifications and parameters of the NDCEE Honeycomb Cleaning System.

Honeycomb Cleaning Specifications and Operating Parameters

Specification	Parameter
Part Size	6' x 6' x 4'
Part Weight	250 lbs.
Wash Temperature	80–180°F
Rinse Temperature	80–180°F
Dry off Temperature	300°F

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Honeycomb Cleaning System.

Original Purchase Cost and Current Value of the Honeycomb Cleaning System

Purchase Cost	Current Value	Years of Service
Donated to the NDCEE by the Air Force	Not Applicable	8

Technology Benefits and Advantages

- Aqueous/semiaqueous closed-loop system that is good for replacing solvent cleaning
- Environmentally friendly

Technology Limitations and Disadvantages

- Designed for honeycomb cleaning (nozzles within the cabinet are set up for this application)
- Is not as versatile as some other types of aqueous cleaning systems

Recommended Upgrades for Continued DoD Support

The Honeycomb Cleaning System is not currently in operational condition. However, no upgrades to the system are recommended until such time as a need for the equipment is identified.

Potential Technology Transfer Applications

This technology could be used for applications that have difficult-to-clean parts with strict cleaning requirements such as aircraft honeycomb.

DoD Need

Environmentally compliant cleaning methods

Service Need Numbers

Army: 2.I.h, 3.2.j

Navy: 2.I.01.g, 3.I.11.b, 3.I.13.a, 3.II.03.a

Honeycomb Cleaning System

Ion Beam Assisted Deposition System

Overview

Most DoD repair facilities use “wet” processes to apply cadmium, chromium, and other surface coatings to a variety of aerospace, tank, automotive, and armament components. Cadmium and chromium are important metals because they impart essential physical and mechanical properties to the surface of the component that is being coated to extend its useful life. The use of traditional wet processes results in the generation of heavy metal wastes that require expensive treatment. The DoD and private industry have been searching for alternative processes that generate little or no waste, are environmentally acceptable, and pose reduced exposure risks to operators. These alternative application technologies must meet stringent performance requirements while remaining technically and economically feasible.

Ion beam assisted deposition (IBAD) is a coating process that incorporates both a means of physical vapor deposition and simultaneous ion bombardment. During processing, the substrate surface is bombarded with positively charged ions while neutral species of the coating material are delivered concurrently to the substrate via a PVD technique such as thermal or electron beam evaporation, cathodic arc, or sputtering. IBAD typically operates at a pressure of approximately 10^{-4}–10^{-5} Torr and typically utilizes low-energy ion bombardment with high beam current, high-energy ion bombardment with low beam current, or a moderate beam energy and current. The impinging ions provide nucleation sites for the neutral species, and at high energies, ion beam mixing can generate a physically mixed zone between the substrate surface and the coating, resulting in increased adhesion. Other benefits that are gained with this process include reductions in porosity and pinholes and increased control of internal stress, morphology, density, and composition.

The thickness of the coating is limited at present to deposits ranging up to several micrometers. The coating species can be virtually any element, compound, or alloy that is capable of being vapor deposited. The gaseous ions may be either inert or reactive (e.g., argon or nitrogen, respectively). Hard coatings of interest for wear applications generally include titanium nitride, chromium nitride, alumina, and other ceramic coatings. These coatings generally are used for high-cost or value-added components. Substrates include metals, plastics, ceramics, and glasses.

The NDCEE identified ion beam processing as an alternative to traditional electroplating technologies. The IBAD process generates minimal waste, poses very few health risks, and can provide superior surface properties.

Specifications

The following table contains the chamber dimensional specifications for the NDCEE IBAD System.

IBAD System Chamber Dimensional Specifications

Chamber Dimensions	Main Chamber	Extension	Load Lock
Length (inches)	72"	42.25"	48"
Diameter (inches)	72"	36"	36"

The chamber dimensions allow the IBAD unit to accommodate components up to 6' in length, 1' in diameter, and 2,000 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE IBAD System.

Original Purchase Cost and Current Value of the of IBAD System

Purchase Cost	Current Value	Years of Service
$ 1,980,000	$ 990,000	6

Technology Benefits and Advantages

- Generates minimal waste
- Reduces health risks
- Provides superior surface finishes with respect to the current processes in use
- Is more environmentally friendly than traditional coating processes

Technology Limitations and Disadvantages

- Specific technologies can impose constraints; for example, line-of-sight transfer makes coating components with a deep internal diameter practically impossible.
- System requires large initial capital investments.
- The means of manipulating parts can be expensive.
- Coating thickness is limited to several micrometers, as opposed to several mils for electrodeposited films.

DoD Need

Environmentally compliant surface protection and corrosion control

Service Need Numbers

Air Force: 200-311, 900-1952

Army: 3.1.c, 3.10.f

Navy: 3.I.03.e, 3.I.04.h

Recommended Upgrades for Continued DoD Support

The following upgrades are recommended for DoD support:

- Although the current IBAD equipment that is located at the NDCEE Demonstration Facility is considered to be state-of-the-art technology, it would be beneficial for this equipment to have a planetary gear fixture installed. This upgrade would provide the following benefits to the equipment:
  - Ability to coat multiple, complex-shaped components
  - Ability to treat more parts in a single trial, making the process more cost-effective
  - Improvements in base materials for parts that cannot be coated due to dimensional constraints.
- A commercial-off-the-shelf moderate energy ion source may increase the reliability of the process by decreasing lead times regarding maintenance. Currently, the moderate energy ion source that was provided with the IBAD system is a custom design. As such, minor maintenance issues require increased attention and longer solution times.
- The addition of other means of physical vapor deposition (e.g., cathodic arc or sputtering sources) would improve deposition rates and enable a wider range of materials to be evaporated.
- The addition of a metal ion source to enable metal ion implantation into substrate materials for improved hardness and wear resistance would be beneficial. As such, materials that do not form nitrides, such as nickel, could be treated.

Ion Beam Assisted Deposition Chamber

- New cryopumps with quicker adsorption rates for gases would benefit this equipment.

Representative NDCEE Tasks

Ion Beam Processing for Environmentally Acceptable Coatings (Task N.001)

- Gathered baseline data regarding current components, such as landing gear, pistons, and cylinder assemblies, that are refurbished with electroplated cadmium and chromium
- Identified ion beam processing methods as potential alternatives to electroplated cadmium and chromium
- Designed the ion beam system based upon the baseline information

Sustainable Green Manufacturing (Tasks N.213 and N.301)

- Conducting research in coatings development, corrosion prevention, and environmental engineering
- Treated parts for testing and performed cost-benefit analyses of same treatments

Materials and Processes Partnership for Pollution Prevention (Task N.227)

- Evaluated ion beam and plasma-based alternatives to chrome plating of gas turbine engines

Corrosion Measurement and Control (Tasks N.255 and N.304)

- Identifying and investigating environmentally friendly corrosion preventative technologies
- Developed corrosion and wear preventive coatings

Potential Technology Transfer Applications

The IBAD process was investigated for use on a variety of weapons systems. In some instances, the coating or surface modification was found to be technically acceptable; however, it was not economically feasible. As shown below, in other applications (including parts that require improved engineering properties), the coatings are to be evaluated by the original equipment manufactures or depot facility to determine technical and economic feasibility. Applicable weapon systems include:

- M1 intermediate and anti-friction, bearing housings - ANAD
- Helicopter drive shafts and gear scuff samples - Boeing Mesa
- M2A2 (Bradley) output carriers and transmission bearing assemblies (races and bearings) - RRAD
- DDC series 60 engine valve stems and seats - Eaton
- Diesel water pump seals
- Boeing outer diameters of rings
- Bearing hubs - ANAD and TACOM
- Duo cone seals for Marine Amphibious Assault Vehicle - General Electric (GE)
- Test coupons for the preliminary corrosion testing for GTE components - GE
- M1A1 bearing cups - ANAD
- AGT 1500 main engine bearings - ANAD
- B-2 bomber bomb door hinge - Boeing

Ion Exchange Units

(Kinetico Ion Exchange Mobile Unit and Kinetico Bench-Scale Ion Exchange Unit)

Overview

Ion exchange technology can be utilized for many purposes. It is often used for polishing drinking water or wastewater for discharge, removing contaminant metal ions from rinsewaters and dilute etching solutions, recovering mineral acids from spent electroplating solutions (efficiencies of >95%), and removing organic contamination from a variety of water sources.

Ion exchange functions by performing an exchange of ionic species between the resin and the process solution. The resin is uniformly charged, either positive or negative, with an oppositely charged ion that is attached to the resin (generally hydrogen ion or hydroxyl ion). When the process solution is passed over the resin, the resin exchanges the hydrogen or hydroxyl for the more strongly charged contaminant ion. Resin materials can be composed of strong base anionic (SBA) materials, weak base anionic (WBA) materials, strong acid cationic (SAC) materials, weak acid cationic (WAC) materials, various chelating agents, mixed bed resins (both cationic and anionic), or granular activated carbon (GAC) for organic contaminant removal.

The NDCEE Demonstration Facility has both full-scale and bench-scale units. These units can be configured with any of the above resin materials or combinations of resins, such as an anionic resin bed, followed by a cationic resin bed, with a GAC bed for polishing at the end.

Specifications

The following table contains the specifications and parameters of the NDCEE Ion Exchange Units.

Ion Exchange Units Specifications and Operating Parameters

Specification	Parameter
Flow Rate	Full-scale unit - 1 gpm Bench-scale unit - 0.1 gpm
Resin	SBA, WBA, SAC, WAC, GAC, various chelating
Resin Beds	4, sequential
Material of Construction	CPVC

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Ion Exchange Units.

Original Purchase Cost and Current Equipment Value of the Ion Exchange Units

Purchase Cost	Current Value	Years of Service
$250,000	$104,167	7 (for each piece)

Technology Benefits and Advantages

- Helps to meet compliance with strict discharge regulations
- Reduces chemical costs and waste volume by purifying and recycling contaminated water
- Improves water quality
- Lowers operating costs for waste treatment and capital costs for chemicals
- Reduces hazardous waste
- Has compact design for efficient use of space

Technology Limitations and Disadvantages

- Some resins can be expensive.
- Presence of contaminants (e.g., oil and grease, oxidants, or acidity) may impact resin selection or require filtration prior to ion exchange.

Recommended Upgrades for Continued DoD Support

The NDCEE maintains the full-scale and bench-scale ion exchange units in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the units are recommended.

Representative NDCEE Tasks

U.S. Navy - Evaluation of Adsorption Technology to Recover Contaminated Mineral Acid Solutions (Task N.064)

- Tested acid recovery from a wide range of simulated waste acid streams

Office of Industrial Technology Program Coordination (Task N.133)

- Demonstrated the ability to regenerate a spent anion exchange resin bed
- Determined the breakthrough point and optimum processing conditions by running a plating solution through the bench-scale unit

NDCEE Demonstration Projects - Alternative Cleaning Solution Recycle/Recovery (Task N.000-01, Subtask 5)

- Evaluated environmentally friendly alternatives to alkaline rust removers

Potential Technology Transfer Applications

This technology could be used for the following applications: polishing drinking water or wastewater for discharge, removing metals from rinsewaters and diluting etching solutions, recovering mineral acids from spent electroplating solutions, and removing organic contamination from water sources.

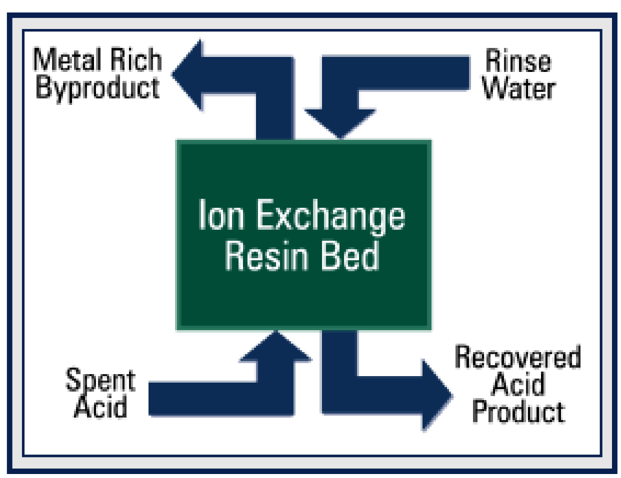
DoD Need

Improved treatment of effluent discharges

Service Need Numbers

Army: 2.2.a, 2.2.e, 2.2.f

Navy: 2.II.01.q, 3.I.03.b, 3.I.11.b, 3.I.11.j, 3.I.13.a



Ion Exchange Process

Ion Plating System

Overview

Ion plating is a physical vapor deposition coating process in which the basic mechanism is an atom-by-atom transfer of material from the solid phase to the vapor phase and back to the solid phase, gradually building a film on the surface to be coated. The three fundamental steps of ion plating include:

1. Vapor phase generation from coating material stock by:
   - Evaporation (resistive or electron beam)
   - Sputtering
   - Cathodic arc.
2. The transfer of the vapor phase from source to substrate (evaporant transition) by:
   - Line-of-sight
   - Molecular flow
   - Vapor ionization by applying a bias to the substrate to attract the ionized material.
3. Deposition and film growth on the substrate.

These steps can be independent or superimposed on each other depending on the desired coating characteristics. The final result of the coating/substrate composite is a function of each material's individual properties, the interaction of the materials, and any process constraints that may exist.

DoD Need

Environmentally compliant surface protection and corrosion control

Service Need Numbers

Army: 3.1.c

Navy: 3.I.03.e, 3.I.04.h

The selection criteria for determining the best method of ion plating is dependent on several factors:

- Material to be deposited
- Rate of deposition required
- Limitations imposed by the substrate such as the maximum deposition temperature, size, and shape
- Coating adhesion to the substrate
- Throwing power [rate and thickness distribution of the deposition process (i.e., the higher the throwing power, the better the process ability to coat irregularly shaped objects with uniform thickness)]
- Purity of coating materials
- Equipment requirements and their availability
- Cost
- Ecological considerations
- Abundance of deposition material

Ion Plater

Ion plating is a desirable alternative to electroplating. It can be applied using a wide variety of materials to coat an equally diverse number of substrates. The application of ion plating surface coating technologies at large-scale, high-volume operations will result in the reduction of hazardous waste being generated when compared to electroplating and other metal finishing processes that use large quantities of toxic and hazardous materials.

Ion vapor deposition (IVD), a subset of ion plating, of aluminum is a vacuum coating process that is commonly used in DoD repair facilities as a replacement for cadmium

plating. The IVD aluminum coating is used as a substitute for electroplated cadmium because it offers satisfactory corrosion resistance for many applications. A variety of other metals may be deposited by ion plating for applications requiring resistance to corrosion, wear or erosion.

Specifications

The following table contains the specifications and parameters of the NDCEE Ion Plating System.

Ion Plating System Specifications and Operating Parameters

Specification	Parameter
Chamber size	6' diameter x 12' length
Sample size	4' width x 7' length x 16" height maximum

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Ion Plating System.

Original Purchase Cost and Current Value of the Ion Plating System

Purchase Cost	Current Value	Years of Service
$1,150,000	$383,333	8

Technology Benefits and Advantages

- Does not require hazardous materials nor does the process generate hazardous wastes. Reduction of hazardous waste helps facilities to meet the requirements of waste reduction under RCRA, 40 CFR 262 and also may help facilities to reduce their generator status and lessen the amount of regulations (i.e., record keeping, reporting, inspections, transportation, accumulation time, emergency prevention and preparedness, emergency response) that they are required to comply with under RCRA.
- Can produce coatings that provide abrasion and corrosion-resistant surfaces (if appropriate materials and appropriate methods of ion plating are chosen).
- Can utilize virtually any type of inorganic and some organic coating materials on an equally diverse group of substrates and surfaces using a wide variety of finishes. In addition, it permits the usage of more than one technique for depositing a given film.
- Uses considerably less water than the traditional electroplating operations, as required under Executive Order 12902, *Energy Efficiency and Water Conservation at Federal Facilities*.
- Has numerous applications to aerospace, tool, automotive, home appliance, hardware, jewelry, and other parts that require coatings for protection, aesthetic appeal, or both.

Technology Limitations and Disadvantages

- Temperature constraints may limit the degree to which dense coatings can be deposited on some plastics.
- Specific technologies can impose constraints; for example, line-of-sight transfer makes coating annular shapes difficult, if not impossible.
- If high biases are being used, areas of the chamber can get hot to the touch and aspects of the chamber require cooling. Operator monitoring is required to ensure that water cooling continues throughout the deposition.

- Selection of the best technology may require experience and/or experimentation.
- This technology requires a cooling water system to dissipate large heat loads.
- This technology has high capital costs.

Recommended Upgrades for Continued DoD Support

This system recently has been upgraded to improve controls and impart a pulsed high voltage bias during deposition. However, the sputtering sources and the program for the sputtering sources and the cathodic arc also could be upgraded.

Representative NDCEE Tasks

Sustainable Green Manufacturing (Task N.213)

- Developing life-cycle-based, environmental improvements in coatings and corrosion prevention
- Testing alternative finishes on DoD components for improved wear and corrosion protection

Materials and Processes Partnership for Pollution Prevention/Pollution Prevention Initiative (Task N.227, Mod 1)

- Demonstrated the efficacy of the proposed environmentally friendly materials/ processes
- Validated alternative technologies prior to implementation

Corrosion Measurement and Control (Task N.255)

- Identifying, investigating, and developing environmentally friendly technologies to measure, control, and prevent corrosion

Potential Technology Transfer Applications

This technology could be applied to those applications that are searching for an environmentally preferred alternative to traditional wet surface finishing processes such as electroplating. Other applications include parts that require improved engineering properties.

Liquid Coatings Application Equipment

(Conventional Spray)

Overview

The liquid coatings application equipment in the NDCEE Demonstration Facility consists of two open-face, cross-draft, paint spray booths (approximately 8' x 3' x 10'). The spray booths are designed with a triple combination of over-spray filters that minimize the size and amount of the particulate reaching the exhaust plenum. This design keeps the exhaust duct and plenum very clean and virtually eliminates particulate emissions. Liquid spray equipment presently consists of several conventional air atomizing and high-volume, low-pressure (HVLP) applicators, air assisted-airless application equipment, and a HVLP turbine-heated air spray system.

Specifications

The following tables contain the specifications and parameters of the NDCEE Liquid Coatings Application Equipment.

Conventional Air Atomizing Applicators Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	60–90°F
Operation Pressure	20–60 psi
Flow Rate	75–250 cc/min
Maximum Part Size	4' x 6' x 3'
Maximum Part Weight	250 lbs.

HVLP Applicators Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	60–90°F
Operation Pressure	7–20 psi
Flow Rate	125–400 cc/min
Maximum Part Size	4' x 6' x 3'
Maximum Part Weight	250 lbs.

Air Assisted-Airless Applicator Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	40–90°F
Operation Pressure	800–3000 psi
Flow Rate	400–1000 cc/min
Maximum Part Size	4' x 6' x 3'
Maximum Part Weight	250 lbs.

Turbine-Heated Air HVLP Applicator Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	90–135°F
Operation Pressure	6–20 psi
Flow Rate	125–400 cc/min
Maximum Part Size	4' x 6' x 3'
Maximum Part Weight	250 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Liquid Coatings Application Equipment.

Original Purchase Cost and Current Value of the Liquid Coatings Application Equipment

Applicator	Purchase Cost	Current Value	Years of Service
Conventional air atomized	$500/gun	$125/gun	9
HVLP	$450/gun	$113/gun	9
Air assisted-airless	$4,000	$2,000	6
Turbine-heated air HVLP	$42,000	$24,500	5

DoD Need

Environmentally compliant coating applications

Service Need Numbers

Air Force: 800-880

Army: 2.I.h, 3.2.a, 3.2.j

Navy: 2.I.01.g

Technology Benefits and Advantages

- Inexpensive application equipment
- Minimal training is needed to use applicators
- Easy to clean-up and maintain application systems
- Handles a wide variety of coating formulations
- Requires only compressed air (clean) utility
- Requires minimal storage space

Conventional Spray Booth

Technology Limitations and Disadvantages

- Current booth size limits ability to coat larger parts and surfaces to demonstrate newer application technologies.
- Booth size limits material choice (i.e., isocyanates) due to limited air drawing power.

Recommended Upgrades for Continued DoD Support

State-of-the-art manually controlled, enclosed generator electrostatic applicators would provide enhanced transfer efficiency and surface finish quality required for most Air Force finishes. Using higher transfer efficiency applicators might allow for coating formulations with less HAP-containing solvents.

Lower-cost, portable turbine-heated air HVLP cup gun systems would provide demonstration of higher-transfer efficiency HVLP application with portability. Portability is required by most large depot maintenance activities and at DoD original equipment manufacturer facilities.

Construction of a larger coating area (20' x 10' x 10') with a state-of-the-art filtration triple filter bank and VFD-driven fan exhaust for maximum ventilation would provide capability to coat larger structures typical of most depot maintenance shops.

Representative NDCEE Tasks

Paint Handling and Spraying Equipment Testing, Evaluation, and Training (Task N.023)

- Utilized as baseline for comparison with alternative coatings application technologies

Environmental Technology Verification Coatings and Coating Equipment Program (Tasks N.100, N.208, and N.306)

- Per EPA Standards, conventional coatings systems are utilized as a baseline when evaluating alternative coatings technology and equipment.

Potential Technology Transfer Applications

All DoD facilities that are currently utilizing conventional coatings technologies to maintain small- to medium-sized components and are in need of additional production capabilities would be potential transfer sites for this equipment.

Membrane Electrolysis Units

Overview

Membrane electrolysis is an electrochemical process that is used to attract oppositely charged particles in solution across a semipermeable membrane. This process can be used to remove metal ion contamination from rinse waters and finishing baths that are utilized in etching, anodizing, and stripping processes. The technology can also be used to reoxidize metal finishing baths and separate acids or bases, causing salt precipitation.

Membrane electrolysis can function by two-compartment or three-compartment methods. For the two-compartment method, the positively charged anode is placed in one chamber and the negatively charged cathode in the other. Either a cation-permeable or anion-permeable membrane is placed between the two chambers. The process solution is then added to the appropriate chamber to achieve the desired type of separation. A voltage is applied to the electrodes and separation proceeds. The three-compartment system has a chamber for the process fluid in the center, with a semipermeable membrane on either side of the chamber. The cation chamber and anion chamber are then on opposite sides of the process chamber, with separation occurring by ions traveling from the process solution, through the membranes, to either outside (cation or anion) chamber.

The NDCEE Demonstration Facility contains a full-scale two-compartment unit, a full-scale three-compartment unit, and a bench-scale unit that can be configured into either two or three compartments.

Specifications

The following table contains the specifications and parameters for the NDCEE Membrane Electrolysis Units.

Membrane Electrolysis Units Specifications and Operating Parameters

Specification	Parameter
Rectifier Rating	20v, 150 amp maximum
Membrane Size	1 ft^2 each
Membrane	Cation, anion permeable
Compartments	2 or 3
Anode Material	DSA, Pt/Ti, or other
Material of Construction	PVDF

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Membrane Electrolysis Units.

Original Purchase Cost and Current Value of the Membrane Electrolysis Units

Purchase Cost	Current Value	Years of Service
$250,000	$83,333	8

Technology Benefits and Advantages

- Helps facilities to comply with strict discharge regulations
- Reduces chemical costs and waste volume by purifying and recycling contaminated water
- Improves water quality
- Lowers operating costs for waste treatment and capital costs for chemicals
- Reduces hazardous waste

Technology Limitations and Disadvantages

- A relatively slow process/batch process
- An electrical process, which may generate noxious fumes
- Nodes and membranes need to be periodically replaced or stripped

Recommended Upgrades for Continued DoD Support

The NDCEE maintains its full-scale and bench-scale membrane electrolysis units in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the units are recommended.

Representative NDCEE Task

Office of Industrial Technology Program Coordination (Task N.133)

- Recovered rinse waters from oxalic acid solution for reuse

Potential Technology Transfer Applications

This technology could be applied in those applications that are looking to have metal ions and impurities recovered from rinse waters and finishing baths. These industries include various plating operations, precious metals recovery, and general cleaning/derusting operations.

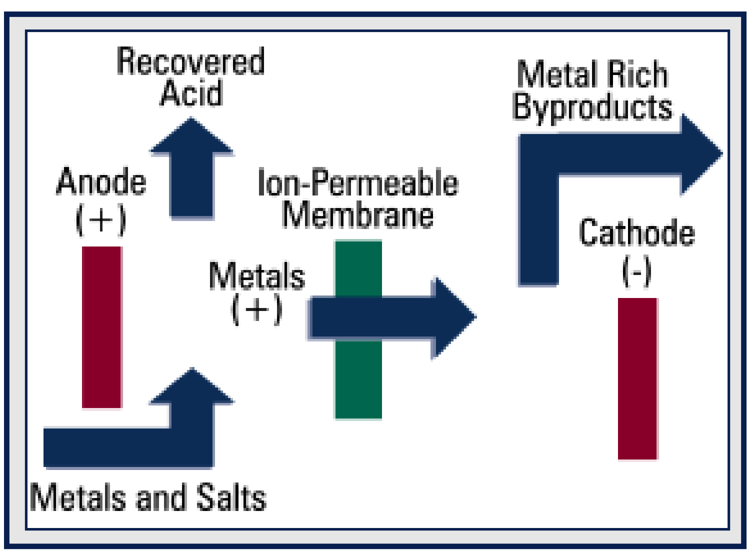
DoD Need

Improved treatment of effluent discharges

Service Need Numbers

Army: 2.2.a, 2.2.f

Navy: 2.II.01.q, 3.I.03.b, 3.I.11.b, 3.I.11.j, 3.I.13.a



Membrane Electrolysis Process

Nonchromate Conversion Coating System

Overview

The full-scale nonchromate conversion coating system is a general-purpose aqueous solution-based pretreatment line. This prototype system can apply most currently available nonchromate conversion coating chemistries and many newly developed ones as well.

The system utilizes a linear design whereby a manual overhead conveyor moves parts from one processing tank to the next. The tanks are organized in stages, with each stage consisting of a process tank, a recirculation tank and two rinse tanks. Because the system was designed for optimum flexibility, any of the processing steps (alkaline clean, alkaline etch, acid etch, desmut, nonchromate pretreatment or sealant) may be omitted, modified, skipped, or repeated as often as desired by the customer's and the processes' specific needs.

The system was designed to apply pretreatment processes using either an immersion or spray application technique. Therefore, the customer can determine the best application technique and its optimal parameters for spray time, concentration, temperature, etc. The system was also designed to handle both spray and immersion rinsing and comes equipped with fogging capability. This capability is generated by the use of special fog nozzles that are mounted within the processing and rinse tanks. The fog nozzles disperse water into a fine mist that gently condenses on the parts as they are being removed from a tank.

The system is extremely flexible and can evaluate any customer requirements in regards to processing parts and proving technical feasibility. Unlike other alternatives, this system incorporates the concept of bath rejuvenation and maintenance. It has quick-connect piping that can be used to individually attach any process tank with treatment technologies such as microfiltration, reverse osmosis, diffusion dialysis, membrane electrolysis, ion exchange, or any other appropriate technique for maintaining and rejuvenating process solutions. This type of process maintenance can save a tremendous amount of raw material usage, waste generation, downtime, and nonconforming product by ensuring that the solution is always as pure as possible.

DoD Need

Environmentally compliant coating system

Service Need Numbers

Air Force: 100-101, 117, 123, 186, 210, 251, 258, 285, 291; 200-312, 337, 339, 852; 800-801; 900-909, 1956, 1989, 2016, 2017, 2018, 2019, 2021, 2089, 2097, 2106, 2110, 2111; 1600-1603, 1647, 1656, 1601, 1640; 1700-1749

Army: 2.1.h, 3.2.a, 3.2.j

Navy: 2.I.01.g, 3.I.04.h, 3.I.13.a, 3.II.04.a

Specifications

The following table contains the specifications and parameters of the NDCEE Nonchromate Conversion Coating System.

Nonchromate Conversion Coating System Specifications and Operating Parameters

Specification	Parameter
Number of Stages	6 (4 polypropylene, 2 stainless steel)
Maximum Part Size/Envelope	2' x 2' x 2'
Maximum Part Weight	250 lbs.
Operating Temperature Range	Polypropylene process tanks - ambient to 170°F Stainless steel process tanks - ambient to 200°F
Tank Capacity	Polypropylene process tanks - 175 gal. Stainless steel process tanks - 200 gal.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE system.

Original Purchase Cost and Current Value of the Nonchromate Conversion Coating System

Purchase Cost	Current Value	Years of Service
$1,384,000	$807,333	5

Technology Benefits and Advantages

- Able to apply most currently available nonchromate conversion coatings
- Capable of both immersion and spray applications
- Capable of rejuvenating process baths using treatment technologies
- Can test and evaluate alternative pretreatments at full scale prior to implementation

Technology Limitations and Disadvantages

- Maximum part size of 2' x 2' x 2'
- Maximum part weight of 250 pounds

Recommended Upgrades for Continued DoD Support

The NDCEE Nonchromate Conversion Coating System is currently able to process most available nonchromate conversion coating chemistries. The equipment is maintained in operational condition, or in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the system are recommended at this time.

Representative NDCEE Tasks

Evaluation of Nonchromate Conversion Coating (Task N.008)

- Designed and built a system to evaluate, at full scale, potential nonchromate alternatives

Organosilane Pretreatment of Aluminum Alloys (Task N.095)

- Evaluated the performance of a nonchromate organosilane aluminum alloy pretreatment

Testing Services to Support the Development of Polyelectrolyte-Modified Zinc Phosphate Conversion Coatings for U.S. Army Tank-Automotive and Armaments Command (Task N.119)

- Conducted a full-scale demonstration of a modified zinc phosphate conversion coating process

Organosilane Pretreatment Process for Aluminum Alloys for U.S. Army Tank-Automotive and Armaments Command (Task N.295)

- Investigated spray application methods for an organosilane pretreatment
- Provided field-level coordination for the implementation of a nonchromate conversion coating at Red River Army Depot

Nonchromate Conversion Coating System

Potential Technology Transfer Applications

The Nonchromate Conversion Coating System may be suitable for any DoD facility that is currently using chromate conversion coatings and for which a nonchromate pretreatment has been identified that meets the requirements of the application.

As a demonstration system, the Nonchromate Conversion Coating System decreases the risk that is involved in implementing nonchromate conversion coating alternatives. The system provides a test bed that presents minimal capital or financial risk to the DoD. This benefit allows the technology to be transitioned from the vendor to the DoD.

Organic Finishing Powder Coating Line

Overview

Powder coating is an environmentally friendly coating process that can be used on a wide assortment of products from bullets to park benches. It provides a durable coating and reduces operating costs while eliminating VOCs, HAPs, and solvent usage. The four basic powder coating methods are electrostatic spraying, conventional fluidized bed, electrostatic fluidized bed, and flame spray. Electrostatic spraying is the most commonly used powder coating application method. For all application methods, high-quality surface preparation (i.e., cleaning and conversion coating) is required to develop good coating adhesion to the substrate. Characteristics of the four different powder application techniques are described below.

In *electrostatic spraying*, an electrical charge is applied to the powdered coating particles while the part that is to be painted is electrically grounded. The applicator and grounded work piece create an electrostatic field that attracts the coating particles to the work piece. The coating particles that are deposited on the work piece retain some of their electrostatic charge, which holds the powder to the work piece. The coated work piece is placed in a curing oven, where the paint particles melt onto the surface and form a continuous film. Due to its versatility, this application method is currently employed in the NDCEE Organic Finishing Powder Coating Line. In addition, the finishing line can apply three types of chemical conversion pretreatments to steel and aluminum parts for adequate adhesion of the powder coatings. Automated conveying and a batch-load, curing oven allow for maximum process control in the handling and thermal curing of the powder-coated parts.

In a *conventional fluidized bed* applicator, powder particles are kept in suspension by an air stream in an engineered dip tank or “bed.” A preheated work piece is placed in the fluidized bed where the powder particles contact with the work piece, melt, and adhere to the surface. Coating thickness is dependent on the temperature and heat capacity of the work piece and residence time in the fluidized powder cloud. Further heating is generally not required when applying thermoplastic powder coatings. However, oven curing is required to cure thermoset powder coatings completely.

Electrostatic fluidized beds are similar in design to conventional fluidized beds, but the air stream is electrically charged as it enters the bed. The ionized air charges the powder particles as they move upward in the bed, forming a cloud of charged particles. The grounded work piece is covered by the charged particles as it enters the chamber. No preheating of the work piece is required; however, curing of the coating is necessary. This technology is most suitable for coating small objects with simple geometry.

The *flame spray technique* was recently developed for application of thermoplastic powder coatings. The thermoplastic powder is fluidized by compressed air and fed into a flame spray gun where it is injected through a flame of propane, melting the powder. The molten coating particles are deposited on the work piece, forming a film upon solidification. Rapid solidification does not allow a smooth film to develop so this technique is not suitable for high-aesthetic surfaces. Because no direct heating of the work piece is required, this technique is suitable for applying coatings to most substrates. Metal, wood, rubber, and masonry can be coated successfully using this technique. This technology is also suitable for coating large or permanently fixed objects.

Powder coatings fall into two basic categories—thermoplastic and thermosetting. The choice of powders is dependent on the end-use application and desired properties. Generally, thermoplastic powders are more suitable for thicker coatings, providing increased chemical resistance and durability, while thermosetting powders are often used when comparatively thin coatings are desired such as decorative coatings. The principal resins that are used in thermoplastic powders are polyethylene, polyvinyl, nylon and fluoropolymer. Thermosetting powders use primarily epoxy, polyester, and acrylic resins.

Powder coating virtually eliminates waste streams that are associated with conventional painting techniques. These waste streams include air emissions, waste streams that are generated from air emission control equipment, and spent cleaning solvents. Powder coating also greatly reduces employee exposure and liabilities that are associated with liquid coating (wet solvent) use. In addition, cleanup times are shorter because overspray can be readily filtered, classified, and reclaimed onsite, regardless of the complexity of the system.

Care must be taken to not mix powders. Colored powders, unlike liquid coatings, will not blend together. Mixing produces discrete colored dots in the final film. Different powder coating resins melt at different rates during curing and will produce "fisheyes" and/or voids in the coating film. In all cases, the dry powder is separated from the air stream by various vacuum and filtering methods and returned to a feed hopper for reuse. Powder coating total material efficiency (powder particles reaching the intended surface) of these systems can reach 95% with reclamation. Other advantages over conventional spray painting include greater durability, improved corrosion resistance, and elimination of drips, runs, and bubbles.

Powder coatings are somewhat limited in their application to aerospace equipment. They typically are not used with primer systems that inhibit corrosion, but they can be successfully applied over many primed and pretreated metal substrates. If primers or pretreatments are not used, the powder coating provides protection as a barrier and prevents corrosion as long as it is intact and undamaged. The temperatures that are required to cure the coating are too high for many materials that are used in aerospace structures (primarily aluminum). However, recently developed formulations allow curing at as low as 250°F, which enables the use of powder coating on most materials. Powder coating can be implemented in high-production facilities with highly automated application systems or on low-volume, manually applied, batch-cured applications.

Specifications

The following table contains the specifications and parameters of the NDCEE Organic Finishing Powder Coating Line.

Organic Finishing Powder Coating Line Specifications and Operating Parameters

Specification	Parameter
Part Size	Up to 2' x 6' x 4'
Batch Size	Small (6 lbs. of powder) to Medium (50 lbs.) to Large (500 lbs.)
Conveyor Speed	Variable, 2–12'/min
Cure Temperature	Variable, up to 450°F
Cure Time	Variable, no limit

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE Organic Finishing Powder Coating Line.

Original Purchase Cost and Current Equipment Value of the Organic Finishing Powder Coating Line

Purchase Cost	Current Value	Years of Service
$2,180,000	$545,000	9

Technology Benefits and Advantages

- No solvent usage; consequent elimination of hazardous air emissions associated with paint applications that use solvents containing HAPs and VOCs.
- Significantly reduced coating cure time in comparison to other paint methods (up to 85%)
- Improved safety and health working conditions
- Material user efficiencies approach 95% because overspray can be captured, filtered, and recycled
- Reduced energy requirements by recirculation of powder coating spray booth air
- Superior finish, greater durability, improved corrosion resistance, and elimination of drips, runs, and bubbles
- Significant cost savings in labor, materials, handling, and disposal of waste
- Effectively employed in the commercial industry for 30 years and is a mature application technology
- New powder coating formulation developments include:
  - Combined IR/UV curing powders that can reduce overall curing time by 50% or better
  - Close-coupled IR curing powders that can keep substrate temperatues below 180°F due to the short cure cycle of the process (5–20 seconds)

DoD Need

Environmentally compliant coating system

Service Need Numbers

Air Force: 100-189, 214, 237; 200-307, 331; 800-837; 1200-1261; 1600-1648; 1700-1756, 1773, 1794

Army: 2.1.h, 3.2.j

Navy: 2.I.01.g, 3.I.04.e, 3.I.04.h

Technology Limitations and Disadvantages

- Powder booth ventilation must be maintained to eliminate explosion hazards (accumulation of suspended particulate). Powder and air mixtures can be a fire hazard when an ignition source is introduced.
- System configurations are partially application specific, but not severely limited.
- Depending on the system, some application limitations may apply such as intricate shapes and assembled components.
- Elimination of coating carrier solvents requires high-quality cleaning and pretreatment processing of parts.

Recommended Upgrades for Continued DoD Support

Since the organic finishing powder coating line was engineered and built for the NDCEE Demonstration Factory, several improvements have taken place in powder coating technology. These improvements both enhance the application control of the different coating materials and open the processing window for coating a wide variety of materials.

Recommendations for purchases to upgrade the coating line operations include the following items: higher-performance electrostatic applicators with voltage feedback control for more complex part coating; digital air logic and electrostatic control systems for improvement in automated powder application process engineering; UV curing lamp system for high-speed coating and select sensitive substrate coating applications such as

magnesium castings and composite structures; and NIR curing tunnel system for sensitive substrate coating applications such as aluminum/plastic/fiberglass composite structures, lightweight magnesium castings, and maintenance/spot repair process development.

Representative NDCEE Tasks

Unitized Coating Application Facility, Electrocoat and Powder Coat (Tasks N.002, N.006, and N.046)

- Evaluated potential substitutes to coating systems containing VOCs and HAPs
- Demonstrated technologies to meet performance and production requirements

Evaluation of Powder Coating Technology for Small Arms Bullet Tip Identification (Tasks N.110 and N.212)

- Evaluated powder coating technologies for reduction in toxic emissions and VOCs, production cost reductions/benefits and increased transfer efficiency

Demonstration/Validation of Powder Coating for Hazardous Waste Minimization from Painting Processes at Rock Island Arsenal (Task N.130)

- Demonstrated powder coatings for elimination of VOCs, ODSs, and HAPs from coating process; increased production rates; decreased waste streams; and improved coatings performance

Sustainable Green Manufacturing (Tasks N.213 and N.301, Subtask R3-8)

- Qualified and validated powder coating as an alternative to solvent-based primer/topcoat used on internal components that were processed at Rock Island Arsenal
- Developed a powder coating specification for Tobyhanna Army Depot based upon facility's needs, available space, and support of new maintenance activities and processes.

Organic Finishing Powder Coating Line

Potential Technology Transfer Applications

Powder coating has many potential avenues for use within the DoD. The potential for coating materials cost reduction, volatile solvent emissions elimination, no HAPs formulations, and reduced overall processing time and labor should provide sufficient incentive for use of these coatings. Use could include all small maintenance part-coating activities and smaller coating facilities. Outsourcing of initial powder coating activities could provide immediate benefits, which include minimizing facilities capital expenditure and site VOCs, qualifying mil-spec powder coatings, and utilizing higher durability coatings while coating materials are integrated into military acquisition and maintenance systems.

Power Washer

Overview

The power washer is a closed-loop, high-pressure spray system that is used to clean and degrease parts that have a relatively simple geometry. A basket can be loaded with parts and lifted onto a rotating turntable by using a jib crane. An aqueous solution is pumped from a reservoir and spray-blasted via a rotating manifold of nozzles onto the parts. A fresh water or deionized rinse removes the solution from the parts before they are hot-air dried. The system also has a bath maintenance feature that uses a process in which suspended contaminants from the solution are removed via centrifugal action. An oil skimmer removes surface oils from the solution before it is recycled to the main reservoir. The solution then passes through another oil skimmer and filter located on the main reservoir. These bath maintenance features help to extend the life of the cleaning solution in the reservoir.

Specifications

The following table contains the specifications and parameters for the NDCEE Power Washer.

Power Washer Specifications and Operating Parameters

Specification	Parameter
Maximum Part Size	3' x 4' x 4'
Maximum Part Weight	5,000 lbs.
Temperature	80–190°F
Variable Flowrate	Up to 350 gpm
Variable Pressure	20–200 psig

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Power Washer.

Original Purchase Cost and Current Value for the Power Washer

Purchase Cost	Current Value	Years of Service
$150,000	$37,500	9

Technology Benefits and Advantages

- Contains a programmable logistics controller that can be programmed for a variety of times and temperatures for each stage of cleaning
- Performs heavy-duty degreasing of many types of components
- Reduces EHS issues associated with solvent cleaning
- Replaces hazardous solvents with an environmentally friendly aqueous cleaner
- Saves costs in labor, materials, handling, and disposal of hazardous waste
- Recycles wash and rinse solutions after filtration, which reduces the wastestream quantity generated

Technology Limitations and Disadvantages

- The part geometries should be simple or medium in complexity for this system to provide the optimum cleaning (no small pin holes).
- The aqueous-based chemistry is not ideal for parts that are prone to rusting.

Recommended Upgrades for Continued DoD Support

The NDCEE maintains its power washer in operational condition. Therefore, no upgrades to the system are recommended.

Representative NDCEE Task

Nonhalogenated Systems for Cleaning Metal Parts (N.007)

- Identified, tested, and evaluated the most environmentally compliant, technically and economically feasible nonhalogenated metal parts cleaning system for the widest range of DoD applications

Potential Technology Transfer Applications

This technology could be used in a wide variety of cleaning and degreasing applications. This system is also transferable to those applications that are testing recycle and recovery equipment on aqueous cleaning solutions.

DoD Need

Environmentally compliant cleaning technique

Service Need Numbers

Army: 2.I.h, 3.2.j

Navy: 2.I.01.g, 2.I.01.q, 3.I.11.b, 3.I.13.a, 3.II.03.a

Power Washer - Rear View

Power Washer - Front View

Reverse Osmosis Units

Overview

Reverse osmosis has numerous functions in industry. It can be used for desalination of waters, boiler feed purification, dye purification, and coolant recovery. Reverse osmosis is also used to reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in waste streams before discharge. Other uses include recovery of some types of plating chemicals, heavy metals, and organics from aqueous solutions and rinse waters.

Reverse osmosis is a high-pressure technology that separates ionic species. The process fluid is forced across a semipermeable membrane (sized from 1–20 Angstroms), where the composition and permeability of the membrane is dependent on the application. Membrane-permeable materials pass through to be collected in a water stream. Metals or chemicals can be recovered from the water stream, or the water stream can be concentrated and discarded as waste, as in process fluid purification applications.

The NDCEE Demonstration Facility has both a full-scale and a bench-scale reverse osmosis unit.

Specifications

The following table contains the specifications and parameters for the NDCEE Reverse Osmosis Units.

Reverse Osmosis Units Specifications and Operating Parameters

Specification	Parameter
Flow Rate	Full-scale unit - 5 gpm Bench-scale unit - 0.5 gpm
Operating Pressure	250–1000 psi
Membrane Material	Polyamide and other thin film composites
Material of Construction	316SS

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Reverse Osmosis Units.

Original Purchase Cost and Current Value for the Reverse Osmosis Units

Purchase Cost	Current Value	Years of Service
$250,000	$83,333	8

Technology Benefits and Advantages
- Helps to meet compliance with strict discharge regulations
- Reduces chemical costs and waste volume by purifying and recycling contaminated water
- Improves water quality
- Lowers operating costs for waste treatment and capital costs for chemicals
- Reduces hazardous waste

Technology Limitations and Disadvantages
- High-pressure system that is relatively labor-intensive

Recommended Upgrades for Continued DoD Support
The full-scale and bench-scale reverse osmosis units are maintained in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the units are recommended.

Representative NDCEE Task
Office of Industrial Technology Program Coordination (Task N.133)
- Removed sodium chloride from rinse waters for reuse of rinse waters

Potential Technology Transfer Applications
This technology could be used to recover plating chemicals, metals, and organics from aqueous, spent bath solutions, and rinse waters. This technology can also be used in those applications that involve boiler feed purification and blowdown reclamation, dye purification, coolant recovery, and reduction of BOD and COD in waste streams.

DoD Need

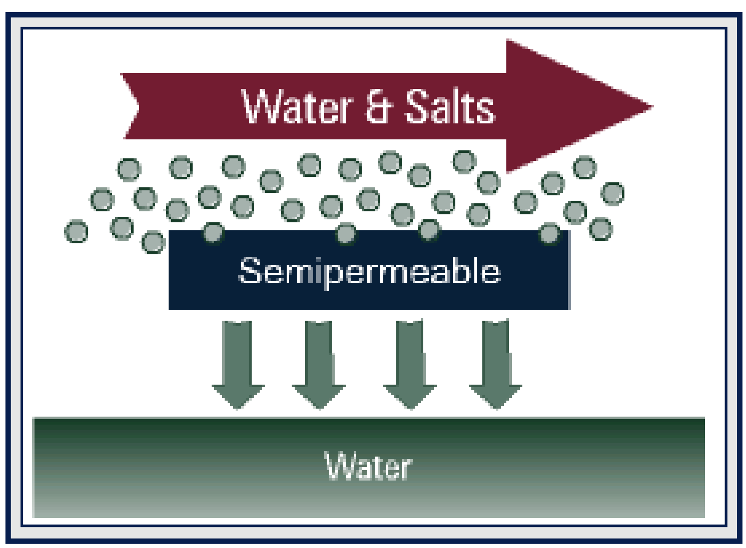
Improved treatment of effluent discharges

Service Need Numbers

Air Force: 900-1979, 1600-1602

Army: 2.2.a, 2.2.e, 2.2.f

Navy: 2.II.01.q, 3.I.03.b. 3.I.11.b, 3.I.11.j, 3.I.13.a, 3.III.06.d



Reverse Osmosis Process

Solid Media Blast Station

Overview

The NDCEE Solid Media Blast Station consists of two standard industrial blast cabinets. The station is used for coatings removal and surface preparation applications. In both instances, solid media, such as steel, alumina, and other grit and shot, are propelled by air against either a coating to be removed or the substrate.

Both blast cabinets are manufactured by Empire Abrasive Equipment Company. Each cabinet is equipped with interior nozzles of various sizes. A Torritt Model air filter serves both blast cabinets.

The larger unit is a Model 7272, which can accommodate parts as large as 58" x 64" x 62" and weighing 1,000 lbs. The reclaimer is rated at 1200 CFM @ 10" standoff position (S.P.) Normally this cabinet is used to process parts requiring more aggressive processing. Alumina and steel grit are the most commonly used media types.

The smaller unit that is used for less aggressive blasting is a Model 2636. Parts as large as 22" x 20" x 30" can be mounted in this cabinet. The reclaimer is rated at 400 CFM @ 6" S.P. Small, soft metal parts requiring glass bead media are usually processed in this unit.

Specifications

The following table contains the specifications and parameters for the NDCEE Solid Media Blast Station.

Solid Media Blast Station Specifications and Operating Parameters

Specification	Parameter
Maximum Part Size (Model 7272)	58" x 64" x 62"
Maximum Part Size (Model 2636)	22" x 20" x 30"
Reclaimer Rate (Model 7272)	1200 CFM @ 10" S.P.
Reclaimer Rate (Model 2636)	400 CFM @ 6" S.P.
Blast Pressure	20–90 psi
Media Mesh Sizes (according to ASTM E11)	8–440

Current Equipment Value

The following table contains the purchase cost and current equipment value for NDCEE Solid Media Blast Station.

Original Purchase Cost and Current Value of the Solid Media Blast Station

Purchase Cost	Current Value	Years of Service
$30,041	$7,510	9 (for each piece)

Technology Benefits and Advantages

- Improves depainting efficiency; removal can be accomplished in a fraction of the time that is associated with manual depainting
- Eliminates use of toxic chemicals
- Meets stringent air pollution requirements
- Is more cost-effective than sandpaper because of recyclable blast media
- Simplifies work process resulting in decreased labor costs due to work being able to be completed by lower-level personnel
- Removes dust to the outside via ventilation system filters

Technology Limitations and Disadvantages

- Regulatory permits may be needed.
- Appropriate solid media is needed for the process.
- Waste disposal includes both the coatings removed and spent media.

Recommended Upgrades for Continued DoD Support

The NDCEE maintains its blast station in operational condition, or in a state from which operation could be restored in less than eight hours. Therefore, no upgrades to the equipment are recommended at this time.

Representative NDCEE Tasks

Sustainable Green Manufacturing (Tasks N.213 and N.301)

- Preparing surfaces prior to ion vapor deposition of coatings

Materials and Processes Partnership for Pollution Prevention (Task N.227)

- Prepared surfaces prior to ion vapor deposition of coatings

Corrosion Measurement and Control (Tasks N.255 and N.304)

- Preparing surfaces prior to ion vapor deposition of coatings

Potential Technology Transfer Applications

This technology could be applied in coatings removal applications.

DoD Need

Environmentally compliant coatings removal technique

Service Need Numbers

Army: 2.1.h, 2.3.k, 3.2.j

Navy: 3.I.05.a

Solid Media Blast Station

Supercritical CO_2 Cleaning System

Overview

The Supercritical CO_2 Cleaning System is a high-pressure cleaning process that takes advantage of the fact that CO_2 in its supercritical state is an extremely effective solvent for many organic materials. It is a cleaning process that penetrates small openings and is especially useful for precision or intricate components such as gyroscopes, accelerometers, nuclear valve seals, laser optic components, special camera lenses, electromechanical assemblies, and porous ceramics. The process works well in removing liquid contaminants, including silicone, petroleum and dielectric oils, flux residues, lubricants, adhesive residues, and fats and waxes. However, it is not very effective on heavy soils or for the removal of particles or salts, except in circumstances where it is used in conjunction with agitation or ultrasonic cleaning.

CO_2 is probably the most widely used fluid in supercritical cleaning applications. CO_2 is especially useful because it is nontoxic, nonflammable, and nonozone-depleting; has a supercritical temperature near ambient temperatures (good for temperature-sensitive parts); and exhibits excellent solvent properties in its supercritical state. CO_2 supercritical cleaning requires high operating pressures in the range of 8–12 MPa, but operating temperatures of only 35–65°C. As a result, most supercritical cleaning equipment has been designed for high-pressure operation and is relatively small. High-pressure cylindrical chambers of supercritical cleaning equipment are intended to hold primarily small, intricate parts or parts with deep crevices, tiny holes, or very tight tolerances that normal alternative precision cleaning processes, specifically aqueous or semiaqueous processes, have difficulty cleaning.

To clean a component using supercritical CO_2, the part is placed in a sealed pressure vessel, which is then filled and flushed with the supercritical fluid. The contaminant-laden stream of CO_2 flows to a separator vessel where it is expanded to a gaseous state. At the lower pressure, the contaminants drop out of solution, allowing for easy separation from the supercritical fluid. The CO_2 is vented to the atmosphere or up to 90% of the gas can be recovered and reused in a closed-loop system. In either case, the CO_2 does not contribute to the waste stream; thus, all treatment and disposal costs are associated with the contaminants only.

Specifications

The following table contains the specifications and parameters of the NDCEE Supercritical CO_2 Cleaning System.

Supercritical CO_2 Cleaning System Specifications and Operating Parameters

Specification	Parameter
Large Cleaning Chamber	5000 psi maximum working pressure
Small Cleaning Chamber	3000 psi maximum working pressure
Low-Pressure Receiver	300 psi maximum working pressure
High-Pressure Receiver	6000 psi maximum working pressure
Supercritical CO_2 System	480 V., 60 Hz., 3 Phase, 40 A
CO_2 tank	480 V., 60 Hz., 3 Phase, 14 A
Shop Air Requirements	120 psi, 1/2" or 3/4" line
Cooling Water Requirements	2 gpm min., 80°F max., 40 psi min., 120 psi max.

Current Equipment Value

The following table contains the purchase cost and the current equipment value of the NDCEE Supercritical CO_2 Cleaning System.

Original Purchase Cost and Current Value of the Supercritical CO_2 Cleaning System

Purchase Cost	Current Value	Years of Service
Donated to the NDCEE	Not Applicable	5

Technology Benefits and Advantages

- Nontoxic surface cleaning and degreasing properties
- Ability to clean complex parts
- Relatively short cleaning times
- Equally high degree of cleanliness to alternate technologies
- Completely dry components following cleaning at room temperature
- Typically closed-loop systems that permit recycling of CO_2

Technology Limitations and Disadvantages

- High capital costs
- Poor removal of hydrophilic contaminants
- High-pressure operations
- Limited component size
- Process parameters that have to be optimized for each specific application and type of contaminant

Recommended Upgrades for Continued DoD Support

The Supercritical CO_2 Cleaning System that is currently housed in the NDCEE Demonstration Facility is a research system and not intended for production-type environments. Currently no upgrades are recommended.

Representative NDCEE Task

Sustainable Green Manufacturing (Task N.213, Subtask R3-2)

- Evaluated CO_2 as a precision cleaning technology for selected metals
- Determined critical parameters for precision cleaning, including cycle time and liquid flush requirements

Potential Technology Transfer Applications

Due to the early stages of this technology and the prototype-based design of the system that is housed at the NDCEE Demonstration Facility, this unit would not currently be a candidate for technology transfer. However, as this technology is further developed, the equipment may have the potential to be transitioned to any facility that is performing, but not limited to, the cleaning of radar connectors, transformers, cables, laser optical benches and o-rings, electronics, optics, and silicon chips.

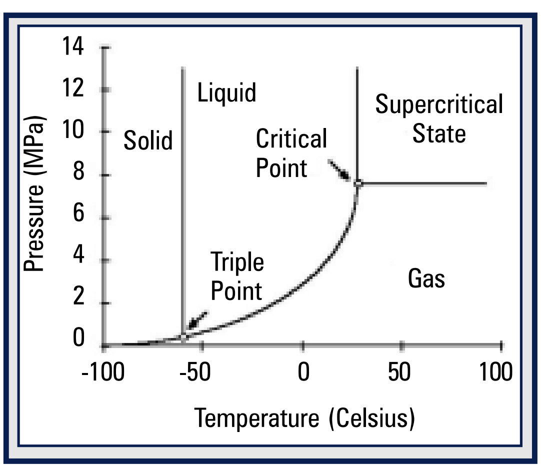
DoD Need

Environmentally compliant cleaning technique

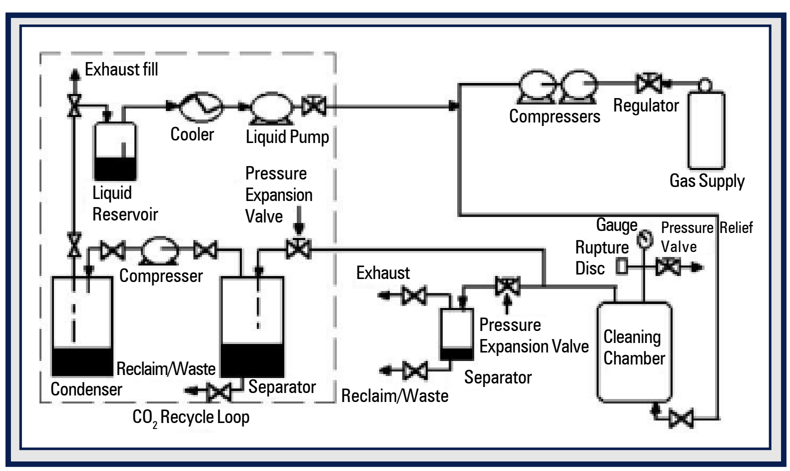
Service Need Numbers

Army: 2.I.h, 3.2.j

Navy: 2.I.01.g, 2.I.01.q, 3.I.14.a, 3.II.03.b



CO_2 Phase Diagram



Typical Supercritical CO_2 Cleaning System

Supercritical CO_2 Coating System

Overview

In the pursuit of lower-VOC coating formulations, supercritical carbon dioxide ($SCCO_2$) can be used to replace carrier solvents in many applications. Liquefied CO_2 and coatings are mixed under pressure and sprayed out of a special atomizing paint applicator. The liquid CO_2 decompresses rapidly upon exposure to ambient pressure, providing a fine atomization of the coating. The resulting coating finish is equal to that of HVLP applications.

This technology is used as both a coating application replacement and as a dispersing agent. It is a safe and effective technology that significantly reduces VOC usage and associated hazards of low solids coatings.

Successful uses of this technology have been with applications of simpler one-component coating systems and pure materials such as edible oils and cleaner/degreaser formulations. VOC levels can be cut by up to 90% when CO_2 is used as a dispersing or thinning agent. Coatings are applied under supercritical conditions of 1600 psi and 35°C, but quickly assume room temperature due to the fine atomization of the spray. This instantaneous decompression of the liquefied CO_2 produces a very confined hazard area of high pressure and the final spray condition appears like an aerosol spray. This technology allows for application of very thin films and coatings.

DoD Need

Environmentally compliant coating applications

Service Need Numbers

Army: 2.I.h, 3.2.j

Navy: 2.I.01.g, 3.I.04.e, 3.I.04.h

Current known commercial applications include application of cooking oil to breaded chicken and fish patties, light protective oiling of three-dimensional surfaces, and dispersing agent for sol-gel coatings.

Use of the $SCCO_2$ technology for coating VOC reduction has been limited due to CO_2's solubility differences with the coating's resin system and remaining intermediate solvents. This solubility difference is further enhanced by use of high-organic solid levels and multiple-component coating systems. Formulations possibly could be tailored to reduced solids, because the majority of coating solvent and subsequent VOCs would be displaced by CO_2; but, this approach has been limited by regulated solids content levels in military and industrial coatings. By increasing CO_2 levels, total application pressures could be reduced and limit the solubility differences in coating.

Initial coating formulations need to be customized (removal of fast solvents at manufacturing point) and intermediate solvents added to produce a pumpable viscosity formulation. Two-component systems will also have to be checked for proper resin-to-catalyst ratios in order to control pot life and dry times. While CO_2 acts as a fast solvent for the system, it is still far more compressible than the solvent that it replaces, and provides little volume dilution (separation) between reactive components.

$SCCO_2$ Spray System

Operators of the $SCCO_2$ Coating System (produced by Linden EMB) require a significant amount of training to determine optimum operating conditions for each coating system. Troubleshooting system problems and flushing out the system after each use are critical due to the higher reactivity of some coatings and potential loss of the supercritical pressure and temperature conditions of CO_2.

Specifications

The following table contains the specifications and parameters for the NDCEE SCCO$_2$ Coating System.

SCCO$_2$ Coating System Specifications and Operating Parameters

Specification	Parameter
Operating Temperature(s)	35–60ºC
Operating Pressure	1200–1800 psi
Flow Rate	500 cc/min.
Minimum Part Size	None
Maximum Part Size	6' x 4' x 3'
Maximum Part Weight	250 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE SCCO$_2$ Coating System.

Original Purchase Cost and Current Value of the SCCO$_2$ Coating System

Purchase Cost	Current Value	Years of Service
$93,000	$54,250	5

Technology Benefits and Advantages

- Reduces VOC levels significantly in coatings and other applied materials
- Reduces coating costs significantly (Liquid CO_2 = $1.70/gallon vs. solvent $5–$10/gallon)
- Works with a variety of coating formulations
- Surpasses HVLP spray coating quality
- Applies coatings very rapidly (high lay-down rate) due to quick release of CO_2
- Has potential to improve transfer efficiency of coatings (controlled atomization)
- Recirculates simple formulations without performance loss
- Reduces environmental impact that is associated with hazardous solvents and solid/hazardous waste that is generated for disposal
- Improves health and safety working conditions and decreases health-related costs (liability risks, protective equipment costs, and monitoring costs) as compared to the use of VOC-containing coatings
- Reduces manufacturing costs as a result of less raw material usage due to higher transfer efficiency
- Produces higher coating delivery rates, reducing overall application time due to lower compressed CO_2 liquid volume in applied coating

Technology Limitations and Disadvantages

- Technology requires complex knowledge of coatings interaction with CO_2.
- Coatings need to be reformulated to remove fast solvents.
- A solvent is still required to flush out the system (can be reused).
- Fine applicator nozzles can plug quickly.
- Capital costs are moderate to high.
- Maintenance costs can be high.

- Extensive equipment training is needed.
- Cleaning of the equipment is more time-consuming than other processes.

Recommended Upgrades for Continued DoD Support

The NDCEE system currently meets or exceeds modern industry standards and is maintained in operational condition. Currently, no upgrades to the system are recommended.

Representative NDCEE Task

UNICARB CO_2 Painting Demonstration for Rock Island Arsenal (RIA) (Task N.205)

- Ongoing effort to develop a methodology for applying Chemical Agent Resistant Coating using the UNICARB system

Potential Technology Transfer Applications

Potential technology transfer sites would include those facilities that are currently looking to reduce HAP and VOC air emissions by the elimination of solvents in coatings applications.

Ultrahigh-Pressure Waterjet

Overview

Waterjets are used for precision industrial applications such as cutting, cleaning, degreasing, debonding, decoating, and depainting. The NDCEE Demonstration Facility contains an ultrahigh-pressure waterjet (UHPWJ) that uses a low-volume stream of pure water at operating pressures between 25,000–55,000 psi. A 6-axis, Fanuc high-precision, industrial pedestal robot manipulates the stream against the parts, which are secured on a turntable. Various rotating blast nozzles, specifically designed to provide the correct energy pattern, are used for coating removal or other applications. Water is supplied to the nozzle assembly by an ultrahigh-pressure, dual-intensifier pump.

An operator controls the robot, pump, and turntable with a user-friendly, menu-driven computer workstation. A teach pendant is used to program the robot's motion. To minimize downtime, the parts turntable is equipped with quick-change toggle clamps to rapidly position and secure work pieces.

The NDCEE waterjet operates as a closed-loop system that eliminates water discharge, reduces water consumption, and concentrates waste for less costly disposal. A pump directs the resulting water/coating mixture to a centrifugal separator that removes most of the particulate matter. The water then passes through a series of filters and tanks for further purification before reuse. The system requires only a small amount of make-up water to compensate for evaporative losses, but both recycled and make-up water must be of sufficient purity so as not to introduce sediments or other impurities that may interfere with the proper functioning of equipment.

Specifications

The following table contains the specifications and parameters of the NDCEE UHPWJ.

UHPWJ Specifications and Operating Parameters

Specification	Parameter
Operating Temperature	75°F, 21°C
Operation Pressure	25,000–55,000 psi
Flow Rate	<2 gpm
Maximum Part Size	6' x 6' x 6'
Maximum Part Weight	1,000 lbs.

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE UHPWJ.

Original Purchase Cost and Current Value of the UHPWJ

Purchase Cost	Current Value	Years of Service
$1,200,000	$300,000	9

DoD Need

Environmentally preferred cleaning and coatings removal technique

Service Need Numbers

Air Force: 100-123, 202, 213, 221, 298; 200-300, 304, 309, 322, 327, 332; 800-814, 900-2095, 1600-1646, 1700-1754

Army: 2.1.h, 2.3.k, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

Technology Benefits and Advantages

- Hazardous waste is reduced by 90%.
- Individual coating layers may be selectively removed with adjustments.
- Prewashing and masking are not needed in most applications.
- A process water reclamation unit captures removed coatings and returns water to the appropriate cleanliness levels for further blasting.
- Process material costs are reduced significantly.
- Labor hours are reduced by 50% for coating removal process.
- No dust or airborne contaminants are generated.
- Specific additives will control flash rusting and give long-term protection.

Technology Limitations and Disadvantages

- Capital costs are high.
- Operator training is required.
- Water can penetrate and/or damage joints, seals, and bonded areas.
- Stripping rate varies with the type of paint, coating condition, and coating thickness.
- This technique is not appropriate for composite or honeycomb thin-skinned materials.
- The medium-pressure water stripping process works well as a supplement to chemical paint stripping, but is not recommended as a stand-alone paint removal process for complete aircraft stripping. It has many successful applications as a part/component stripping process. Medium-pressure water without abrasive additives, such as sodium bicarbonate, will not always remove paint completely.
- The characteristics of the coatings to be removed may impact personal protection and waste collection/disposal considerations.

Recommended Upgrades for Continued DoD Support

The NDCEE UHPWJ cell currently meets or exceeds modern industry standards. The equipment is maintained in operational condition, or in a state from which operation can be restored in less than eight hours. Currently, no upgrades to the UHPWJ cell are recommended.

Representative NDCEE Tasks

Automated Ultrahigh-Pressure Waterjet System Workcell (Task N.020)

- Removed flame spray coatings from jet engine components
- Removed paint from aircraft fuselage
- Removed metallic flame spray coatings from helicopter engine components
- Conducted software and hardware training for operators and maintenance personnel

New Attack Submarine Support (Task N.087)

- Evaluated, tested, and demonstrated alternative acid etching process of soft tiles

Stripping Methods for Soft Material Tiles on Submarines and Surface Ships (Task N.122)

- Removed soft materials from submarines and surface ships
- Developed vacuum recovery capability

UHPWJ robot removing flame spray coating.

Potential Technology Transfer Applications

The UHPWJ process equipment would be a candidate technology to be transitioned/implemented at any DoD facility that is currently removing coatings from small- to medium-sized components. Additional applications include rubber tire removal from roadwheels, sonar dome cutting, and flame spray removal.

UHPWJ with robotic arm and turntable

Vacuum Evaporator

Overview

Vacuum evaporation is a separation process that is typically used to recover plating chemicals from rinse water or to concentrate wastes from wastewaters. The concentrated wastes may then be either discarded or recovered.

Vacuum evaporation is based on the simple principle that water vaporizes at 212°F, leaving dissolved salts and metals. Unfortunately, some chemicals degrade at this temperature. In a vacuum, however, water boils at lower temperatures, so water and chemicals can be separated without degradation of the chemicals. Both the water and the chemicals can then be reused.

Specifications

The following table contains the specifications and parameters for the Vacuum Evaporator located in the NDCEE Demonstration Facility.

Vacuum Evaporator Specifications and Operating Parameters

Specification	Parameter
Flow Rate	2 gph water
Material of Construction	316SS

Current Equipment Value

The following table contains the purchase cost and current equipment value for the NDCEE Vacuum Evaporator.

Original Purchase Cost and Current Value for the Vacuum Evaporator

Purchase Cost	Current Value	Years of Service
$13,700	$4,567	8

Technology Benefits and Advantages

- Reduces aqueous waste
- Reduces hazardous waste
- Reduces the cost of hazardous waste disposal
- Reduces the cost of drums for hazardous waste disposal
- Can operate unattended

Technology Limitations and Disadvantages

- Technology requires a utility hookup for electricity and may require utility hookups for gas and cooling water.
- Technology may require an air permit for a gas burner (new source) and for evaporation to atmosphere.
- Units require operator training.
- Units must be installed in areas with fire suppression systems.

Recommended Upgrades for Continued DoD Support

The NDCEE evaporator currently meets or exceeds modern industry standards, and is maintained in operational condition. Currently no upgrades to the system are recommended.

Representative NDCEE Tasks

The vacuum evaporator has been used to process wastewater from the closed-loop plating line, which was operating under the following tasks:

Alloy Plating to Replace Cadmium on High-Strength Steels (Task N.000-02, Subtask 7)

- Evaluated commercially available noncyanide alternatives to cadmium plating processes

Environmental Metal Plating Alternatives - Electroless Nickel Plating Rejuvenation (Task N.089)

- Evaluated technologies that are capable of reducing the amount of waste generated by electroless nickel plating processes

Evaluation of Noncyanide Silver Plating (Task N.104)

- Evaluated commercially available noncyanide alternatives to silver plating processes

Materials and Process Partnership for Pollution Prevention/Pollution Prevention Initiative (Task N.227)

- Evaluated commercially available noncyanide alternatives to copper and silver plating processes

Sustainable Green Manufacturing (Task N.301, Subtask R4-1)

- Evaluated commercially available noncyanide alternatives to cadmium plating processes

Potential Technology Transfer Applications

This technology could be applied in those applications that are looking to recover plating chemicals from rinse water or to concentrate wastes from wastewaters.

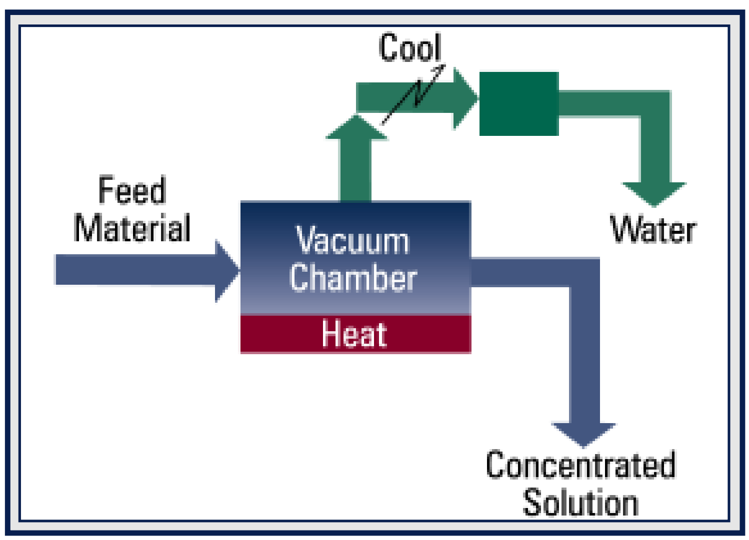
DoD Need

Improved treatment of effluent discharges

Service Need Numbers

Army: 2.2.f

Navy: 2.II.01.q, 3.I.03.b, 3.I.11.b, 3.I.11.j, 3.I.13.a



Vacuum Evaporator Diagram

Xenon Flashlamp/CO_2 Blasting (FLASHJET®)

Overview

The FLASHJET® system is a pulsed-optical energy decoating process. It uses a combination of high-intensity infrared energy that is generated by a high-intensity pulsed Xenon Flashlamp and abrasion from a blast medium of carbon dioxide pellets. The paint is in effect charred, and the residual particles are vacuumed and placed in a storage container.

Traditionally, coating removal activities were performed using chemical or dry abrasive techniques. Due to the use of toxic solvents, the generation of large amounts of solid waste, and the environmental, health and safety concerns that are associated with these conventional processes, alternative coating removal processes are being investigated. One such alternative is the FLASHJET® system.

The FLASHJET® process is an automated process that uses a manipulator robotic assembly to strip coatings from large and small components. The stripper head contains a xenon flashlamp that produces pulsed light energy to break the molecular bonds of the coating. A thin layer of the coating is essentially burned or pyrolyzed. Simultaneously, as the coating is being broken up and the pyrolyzing process is occurring, a dry ice pellet stream is sweeping away the residue while also cooling and cleaning the surface. The removed paint is vacuumed away by an effluent capture system, which consists of HEPA filters and activated charcoal. The effluent capture system separates the ash from the organic vapors by removing the ash through the filters, and the organic vapor through the activated charcoal. The only wastes that are produced by this process are spent HEPA filters, which are tested for hazardous waste (dependent on the coating removed) and disposed of accordingly.

The system has a stripping rate of approximately 270 square feet per hour. The Xenon Flashlamp is guaranteed for 500,000 flashes, which is directly dependent on the power level at which the lamp is operated (typically 1 million flashes are obtained).

Specifications

The following table contains the specifications and parameters for the NDCEE FLASHJET®.

FLASHJET® Specifications and Operating Parameters

Specification	Parameter
Part Size	Approximately 5' x 6' x 6'
Stripping Head	6" Xenon Flashlamp
Power Supply	208 VAC
CO_2 Pellitizer Flow Rate	300–600 lbs./hr
Effluent Capture System Series	Hepa filter —> large fan —> carbon filter —> disposal

DoD Need

Environmentally compliant coatings removal technique

Service Need Numbers

Air Force: 100-202, 213, 298; 200-300, 304, 309, 322, 332; 800-814; 900-2095; 1600-1646; 1700-1754

Army: 2.1.h, 2.3.k, 3.2.j

Navy: 2.I.01.g, 3.I.05.a

Current Equipment Value

The following table contains the purchase cost and current equipment value of the NDCEE FLASHJET®.

Original Purchase Cost and Current Value of the FLASHJET®

Purchase Cost	Current Value	Years of Service
Donated to the NDCEE by the Air Force	Not Applicable	6

Technology Benefits and Advantages

- Does not release hazardous or toxic emissions
- Removes paint from surfaces faster than conventional chemical or mechanical means
- Generates minimal annual waste

Technology Limitations and Disadvantages

- Large capital cost investment
- Large work head

Recommended Upgrades for Continued DoD Support

The FLASHJET® unit that is currently housed at the NDCEE Demonstration Facility does not meet industry standards. Upgrades to meet current industry standards include:

- Upgraded control system including computer and interface hardware
- Upgraded flash tube capability
- Upgraded environmental system.

Based on a similar upgrade proposal, the estimated costs for the upgrades are approximately $200,000.

Representative NDCEE Tasks

Stripping Methods for Hull Treatments (SHT) Tiles (N.122)

- Demonstration and validation activities were conducted on special hull treatment tiles

Tri-Service Demonstration and Validation of the Pulsed-Optical Energy Decoating FLASHJET® Process for Military Applications (Tasks N.126 and N.226)

- Demonstration and validation activities were conducted on CH-53 off-aircraft components
- Completed a cost analysis using the ECAM℠ tool in which FLASHJET® was compared to hand sanding (baseline) for use on Apache and the Blackhawk helicopter rotor blades at Corpus Christi Army Depot

Potential Technology Transfer Applications

Transfer sites include facilities in all branches of the DoD that are currently utilizing abrasive and chemical methods to remove coatings.

FLASHJET® System

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